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Method for estimating the probable volume of railway traffic

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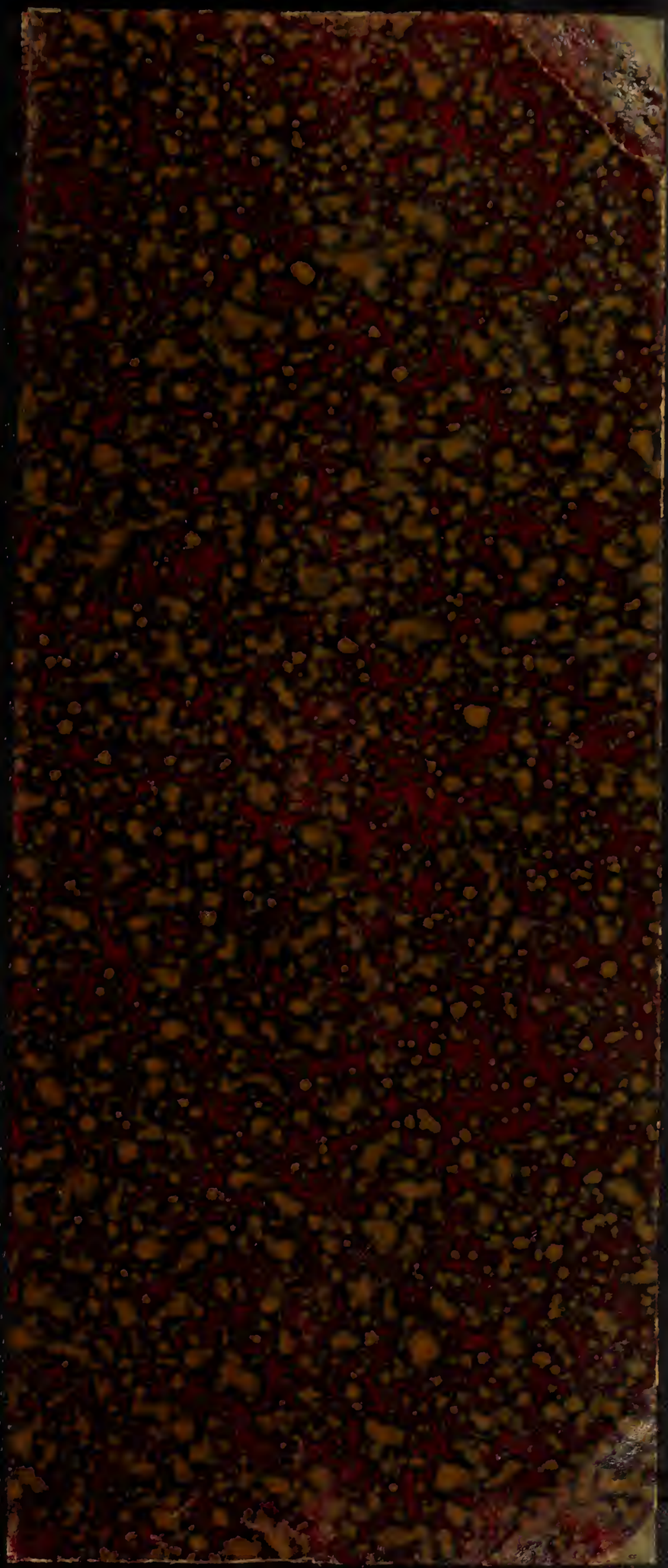

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METHOD FOR ESTIMATING THE PROBABLE VOLUME OF RAILWAY TRAFFIC

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1911

BY

GEORGE WILLIAM RATHJENS

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1910

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This is to certify that the thesis of GEORGE WILLIAM RATHJENS entitled Method for Estimating the Probable Volume of Railway Traffic is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

J. Elmo Smith
Instructor in Charge.

Approved:

Ira O. Baker.
Professor of Civil Engineering.

167150

UFC

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METHOD OF ESTIMATING THE PROBABLE VOLUME OF RAILWAY TRAFFIC

In considering large economic problems pertaining to the betterment of railway properties and to the inception, projection, and financing of new projects, the question, "What will be the probable volume of traffic?" usually presents itself. To determine the volume of traffic with exactness is of course impossible; but by a study of past experience a fairly accurate estimate may be made. As our best guide is the statistics of the past, the author has compiled statistics and has endeavored to put them into such form that they can be used in making an estimate of the traffic to be expected from any given territory whose commercial and social conditions are similar to those of the area from which the statistics were derived.

It is the purpose of this thesis to explain how such statistics may be used in estimating the probable traffic in a given territory at any given time.

For the purpose of this investigation it is necessary to express in mathematical terms the relation between tonnage and the population. It is well known that of all the mathematical curves the parabola is the most flexible and also has the most simple equation. For this reason the author chose the parabola having the equation $X = K y^{\Delta}$, in which X represents the tonnage and y the population, K is a constant, and Δ is an exponent to be determined. In discussions of this character the data can be presented more clearly graphically than otherwise; and therefore the graph of the above equation will be used to represent the relation between the amount of traffic and the population. It remains then to determine the value of the constant K and of the exponent Δ.

It is a well known fact that the equation $X = K y^{\Delta}$ can be represented by a straight line on logarithmic paper, that is, paper divided so that the divisions are proportional to the logarithms of the numbers; and also that the slope of this line determines the value of Δ. The intersection of this line with either axis is determined by K. The value of K must be determined for each particular problem. Then Δ represents the rate of increase of a definite quantity

which is dependent upon K .

To determine the value of $\frac{1}{\Delta}$ the author has plotted upon logarithmic paper the tonnage as ordinates and the population as abscisses. For example, on Plate 2 were plotted the total tons of freight carried one mile by all the railroads in the United States reporting to the Inter-state Commerce Commission, for each of the several years from 1890 to 1907, inclusive; and then by eye a straight line (the black one) was drawn to represent the mean of the several points. The slope of this line is 340 ÷ 985 = 0.347, the value of $\frac{1}{\Delta}$ for the territory and years represented. On Plate 2 are drawn three other lines (in red) having different values of the exponent Δ, to show the effect of a fractional variation in the value of this exponent.

The value of K was determined from the equation $y = K X^{\Delta}$, which contains three known quantities, namely X, y and Δ. The value of K was determined solely to facilitate plotting the equation $X = K y^{\Delta}$ upon plain coordinate paper.

The author used the Inter-state Commerce Commission's territorial division of the United States. The territory embraced by each of these divisions, designated as groups I, II, III, etc., is shown on Plate A, Page 5. The Inter-state Commerce Commission for certain purposes combines the above groups into so-called representative divisions as follows:

Division I comprises groups I, II, and III, i. e., the territory north of the Ohio and Potomac rivers and east of Illinois and Lake Michigan.

Division II comprises groups IV and V, i.e., the territory south of the Ohio and Potomac rivers, and east of the lower Mississippi River.

Division III comprises groups VI, VII, VIII, IX, and X, i.e., the territory west of Lake Michigan, Indiana, and the lower Mississippi River.

The writer found a value of Δ for (1) the total tonnage carried one mile per mile of line, (2) the total tonnage originating on the line per mile of line, and (3) the total tonnage of each of the following classes of products; animal, agricultural, mine, forest, manufactures and merchandise. The total amount of the products in the third item above represents about ninety-five per cent of all the tonnage originating on the line.

The specific commodities included in each of the above mentioned classes are as follows (Classification of Inter-state Commerce Commission):

1. Products of agriculture: grain, flour, other mill products, hay, tobacco, cotton, fruit, vegetables, etc.

2. Products of animals: live stock, dressed meats, other packing house products, poultry, game and fish, wool, hides, leather, etc.

3. Products of mines: anthracite coal, bituminous coal, coke, ores, stone, sand, etc.

4. Products of forests: lumber, etc.

5. Manufactures: petroleum, oils, sugar, naval stores, iron (pig and bloom), iron and steel rails, castings, machinery, bar and sheet metal, cement, brick, lime, wagons, carriages, tools, wines, liquors, beers, household goods and furniture, etc.

On Plate B, Page 6, are tabulated the values of Δ for the several classes of traffic as determined from the data plotted on Plates 1-35.

To apply the preceeding data in the solution of a particular case it is necessary, first, to determine which of the several groups on Plate B most nearly represent the particular territory whose future traffic is to be estimated. We must select the group which determines the value of Δ in the equation used above. Second, the present population of the given territory must be determined. Third, the present traffic in that territory must be found. This gives three of the four quantities in the equation $X = K y^{\Delta}$, and by solving this equation the value of K can be found, since the value of K does not materially change for a series of years when traffic is normal, it may be assumed to be practically constant, and therefore if we can determine the probable future population we can easily determine a value for the probable volume of traffic.

To illustrate the above, let us assume the road under consideration operates in a territory whose social and commercial conditions are similar to those of group V, that there were 22,000,000 tons of freight carried during the past year (1910) and that it is desired to determine the probable tonnage in 1920. Let us assume that the population of the territory from which the line under consideration received its business will be increased 20% during the next ten years, 1910 to 1920. The line operates in a territory similar to group V, Plate B,

and therefore we will use the equation $X = K y^4$ Let y = the population in 1910, which we will represent by 1, Since the increase is 20%, y, the population in 1920, can be represented by 1.20. Using the data for 1910 and substituting in the equation $X = K y^4$ we can derive a value of K.

$$22,000,000 = K \overline{1}^4 \text{ and therefore}$$

$$K = 22,000,000$$

The probable volume of traffic in 1920 will then be represented by X in the formula,

$$X = 22,000,000 \overline{1.2}^4$$

$$= 22,000,000 \times 2.07$$

$$= 45,500,000 \text{ tons}$$

Considering what has been said above and referring to the graphs, it will be noticed; (1) That in a large majority of cases the points representing a maximum, the average of all the points, and the points representing a minimum, lie practically on curves whose exponents are the same, for each of the three cases above mentioned, K being the only variable. However, the data does not cover a sufficient interval of time to permit the drawing of any general conclusions. (2) That there is a relation between tonnage and population and that this relation can be represented by the equation $X = K y^4$. (3) That for years of normal traffic, and for years in which the per centage of deviation from the normal is the same, the value of K may be considered a constant.

The data plotted on Plates 1-22 represents the statistics for the years 1890-1907 inclusive; on Plates 23-31 is shown the data for the years 1900-1907 inclusive; and on Plates 31-35 that for 1899-1907 inclusive.

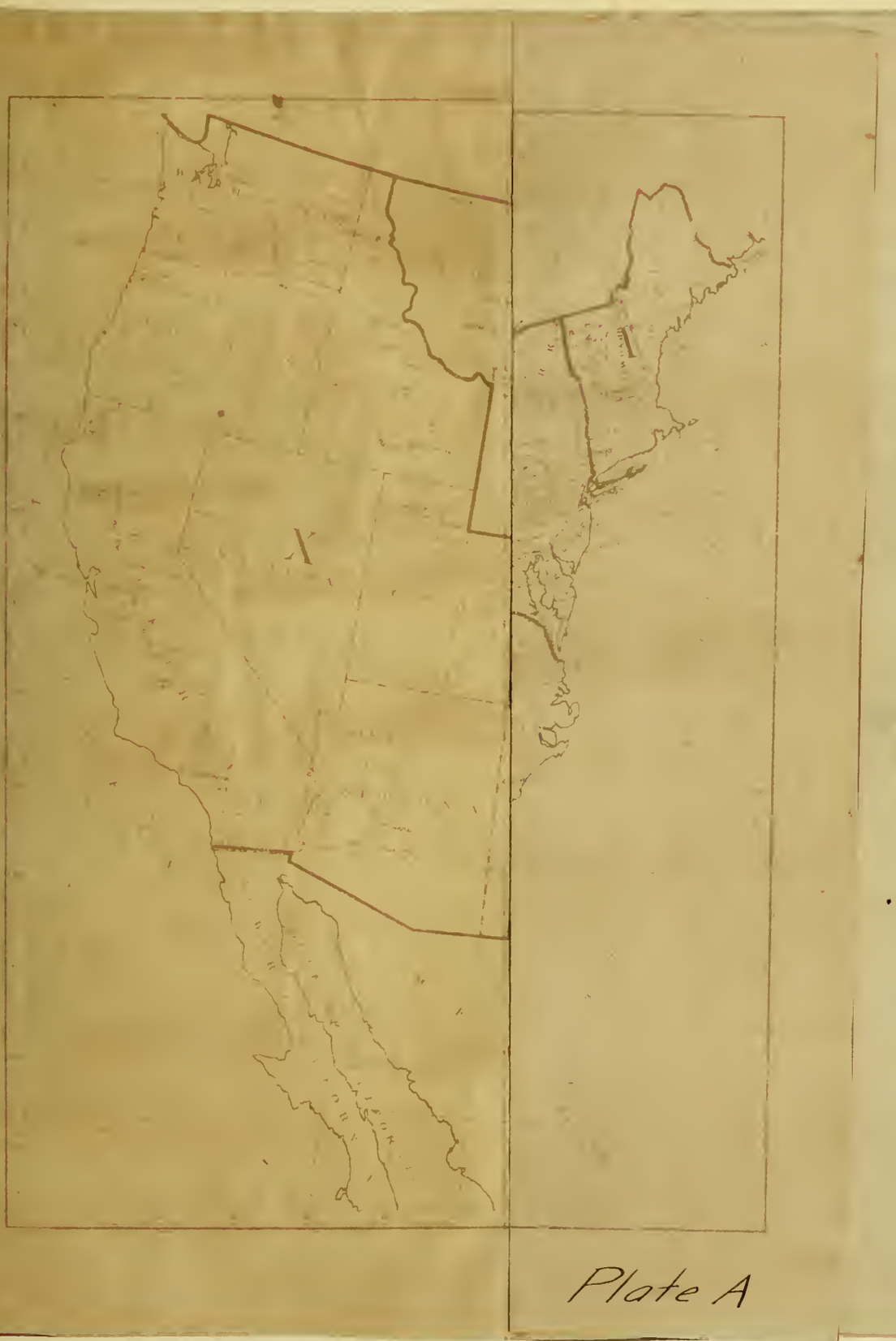


Plate A

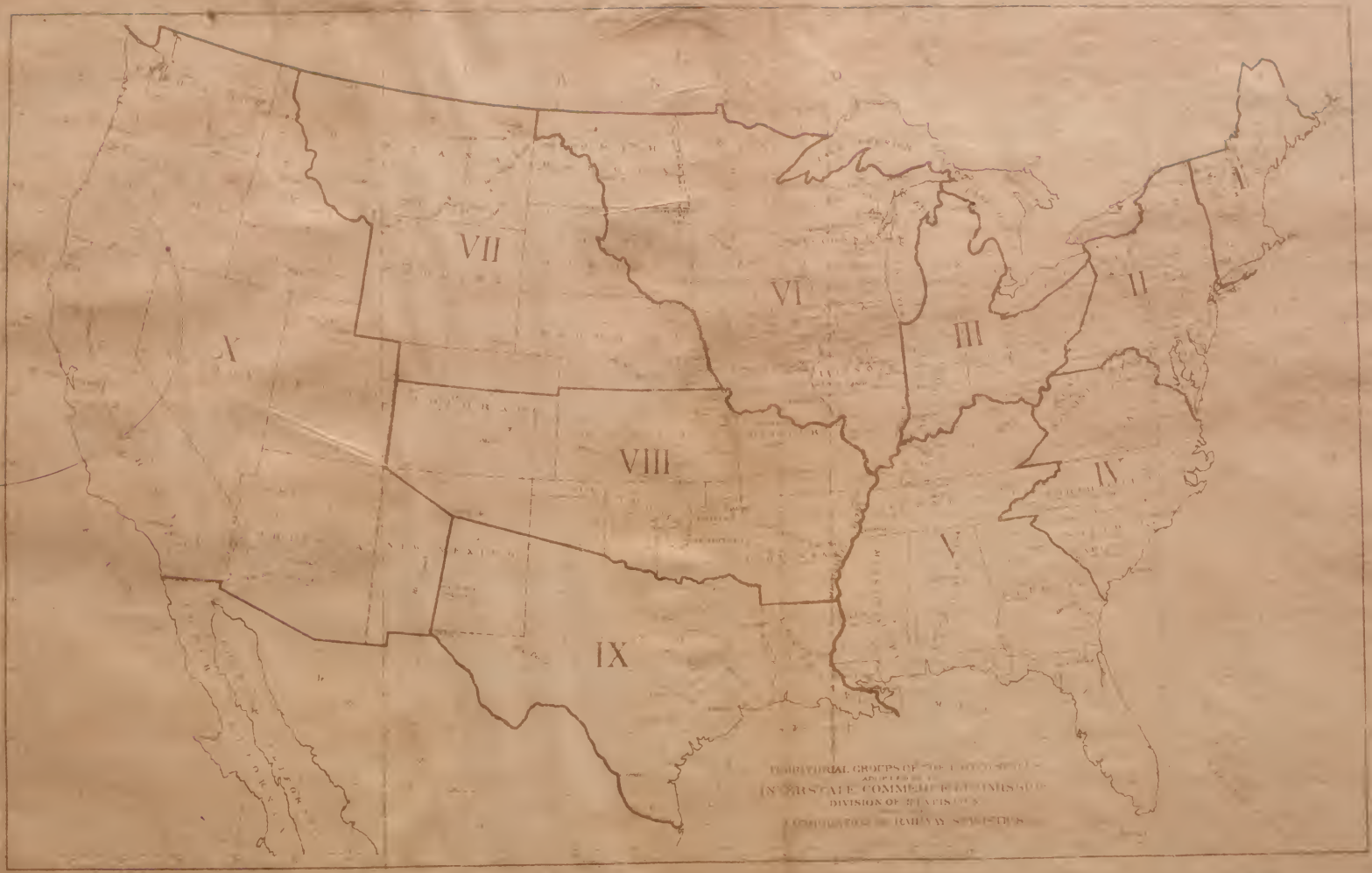


Plate A

Plate B.

$X = KY^{\Delta}$

X = Tons. Y = Population. K = Constant.

Territory	Commodity or Kind of Freight.	Carried one mile or Originating on line.	Value of Δ Approx.	Value of Δ Actual.
United States	Total	Carried one mile	3	$\frac{985}{340}$
Group I	"	" " "	$\frac{5}{2}$	$\frac{982}{420}$
" II	"	" " "	3	$\frac{982}{370}$
" III	"	" " "	6	$\frac{100}{18}$
" IV	"	" " "	5	$\frac{982}{210}$
" V	"	" " "	4	$\frac{100}{23}$
" VI	"	" " "	4	$\frac{740}{165}$
" VII	"	" " "	8	$\frac{984}{118}$
" VIII	"	" " "	3	$\frac{982}{290}$
" IX	"	" " "	2	$\frac{982}{430}$
" X	"	" " "	3	$\frac{982}{288}$
United States.	"	Originating on line.	5	$\frac{500}{104}$
Division I	"	" " "	6	$\frac{250}{41}$
" II	"	" " "	6	$\frac{50}{9}$
" III	"	" " "	5	$\frac{500}{106}$
United States.	Animal Products	" " "	2	$\frac{500}{245}$
" "	Agricultural "	" " "	2	$\frac{340}{165}$
" "	Mine "	" " "	5	$\frac{370}{72}$
" "	Forest "	" " "	4	$\frac{500}{115}$
" "	Manufactured "	" " "	7	$\frac{50}{7}$
" "	Merchandise	" " "	5	5

April 2 1910

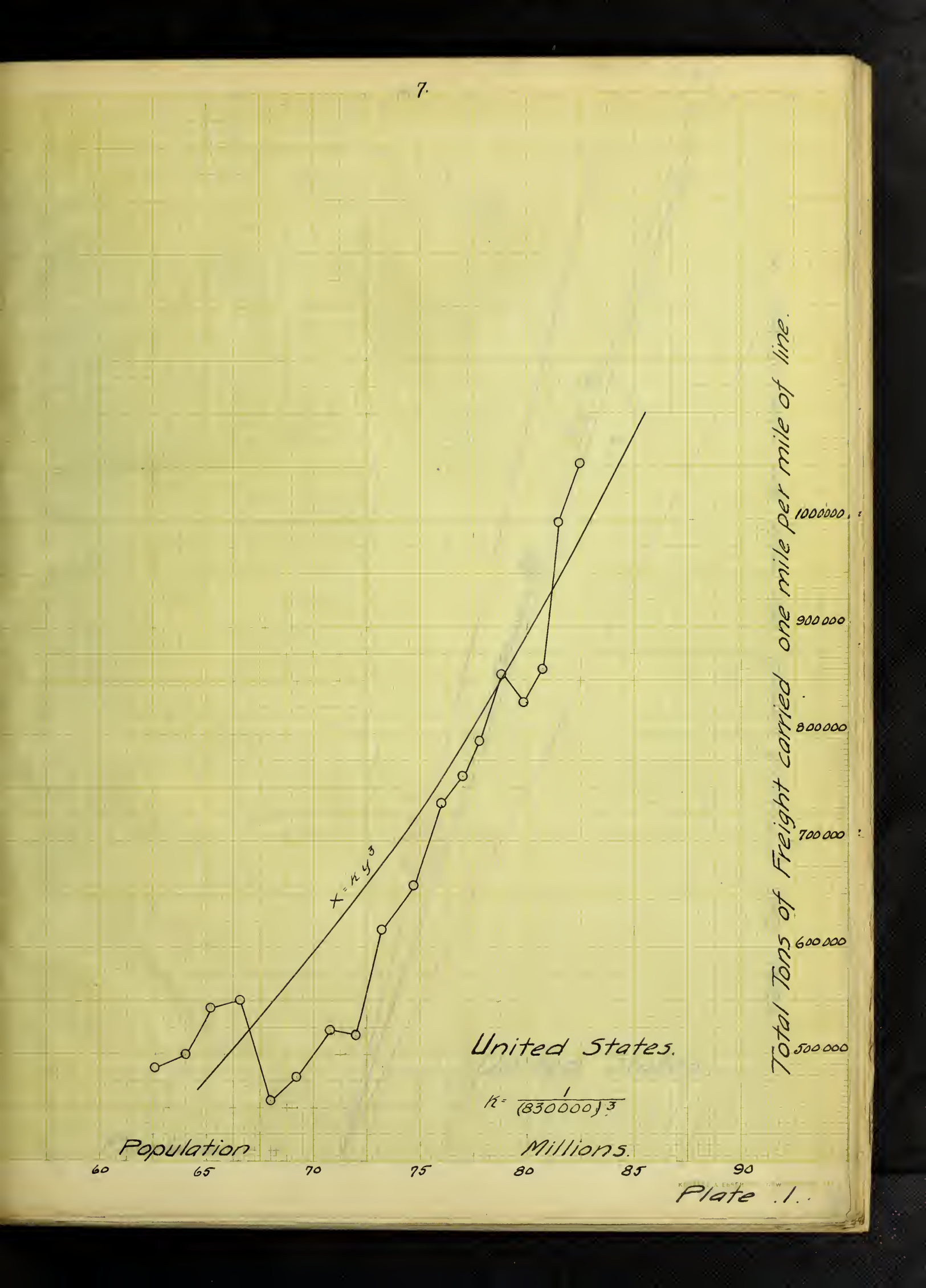
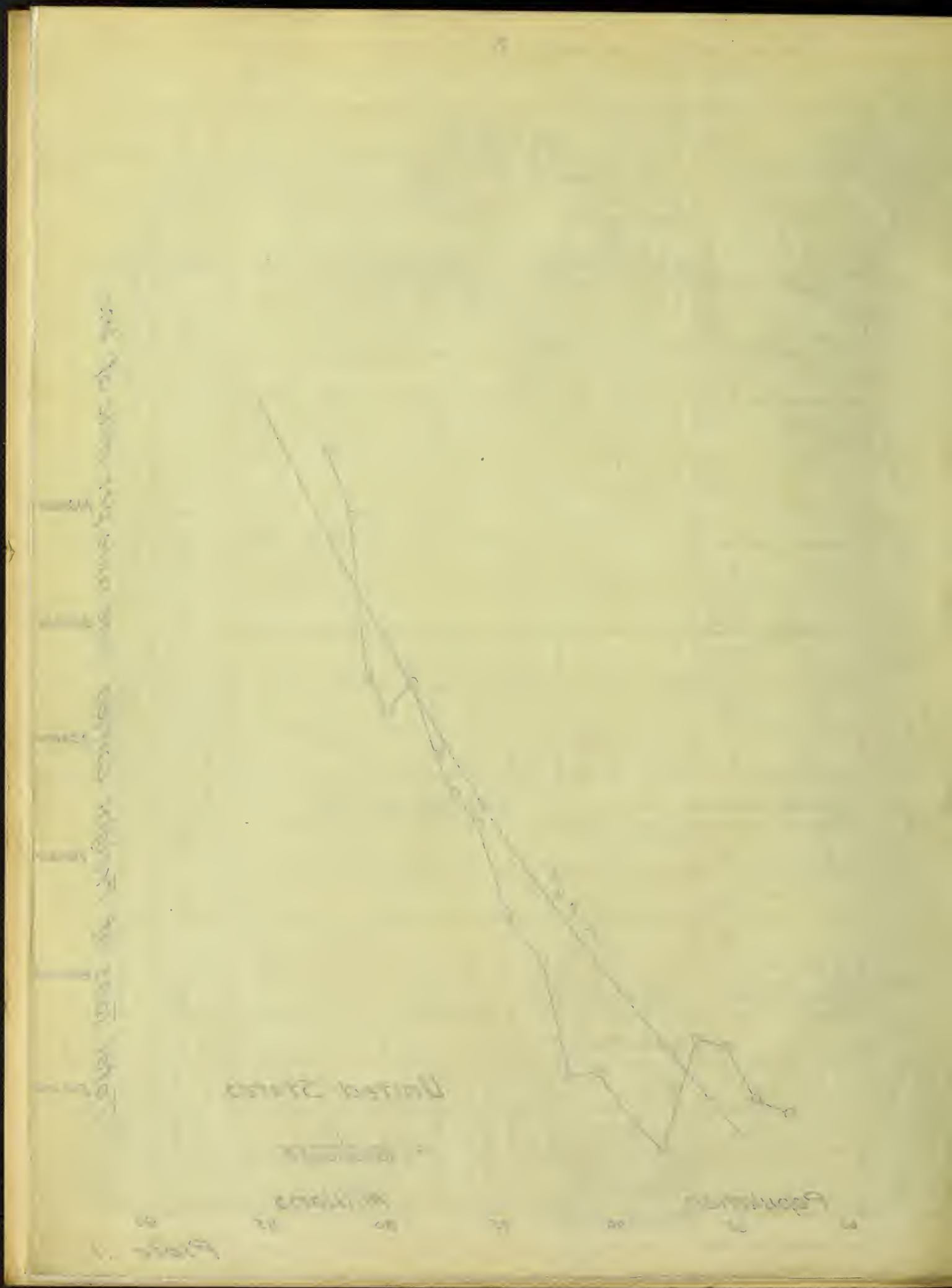

Total Tons of Freight carried one mile per mile of line.
1000000
900000
800000
700000
600000
500000
$x = k y^3$
United States.
$k = \frac{1}{(830000)^3}$
Population
Millions.
60
65
70
75
80
85
90

Plate .1..



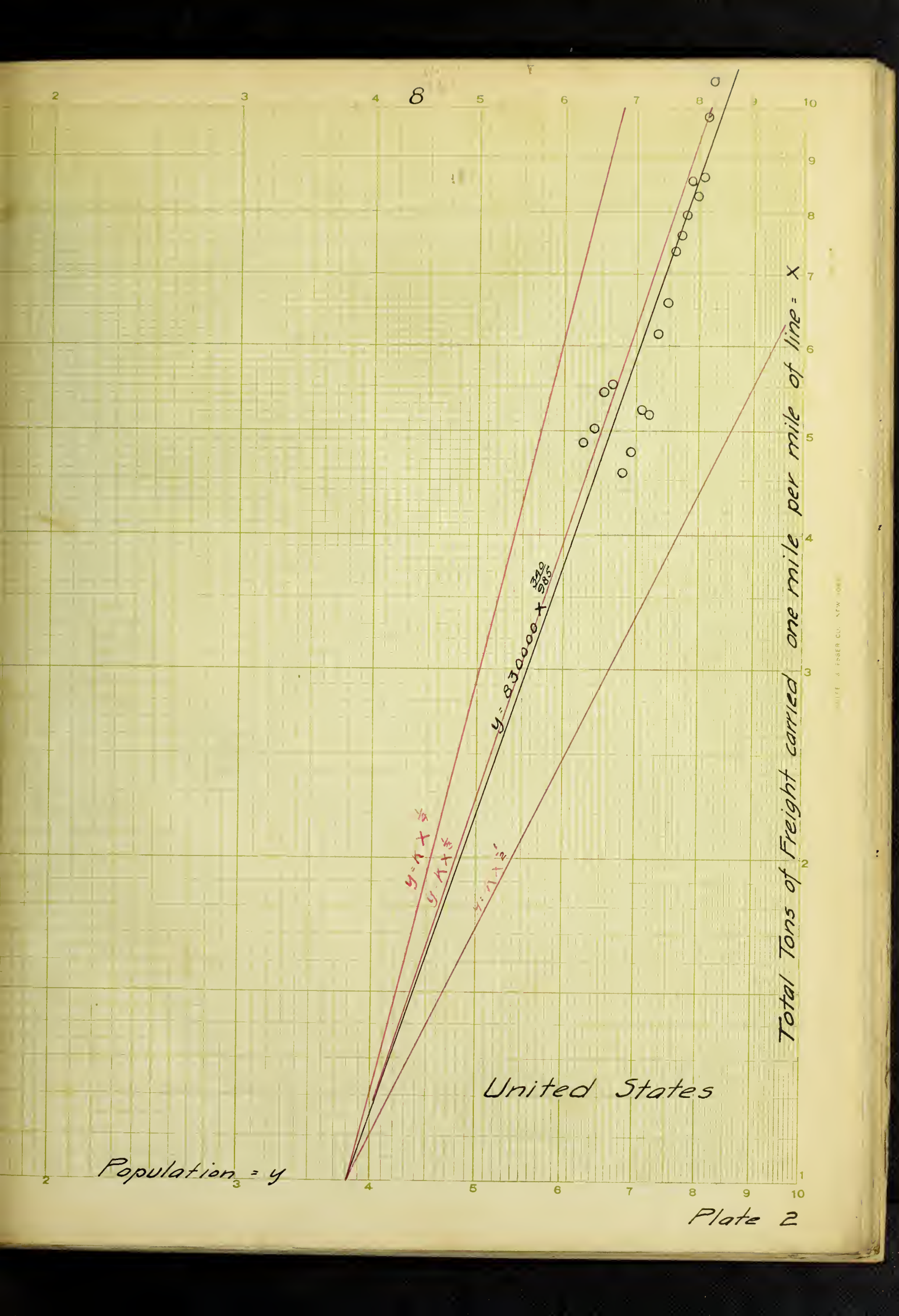

Total Tons of Freight carried one mile per mile of line = x
Population = y
y = 4 x^{3/2}
y = 4 x^{3}
y = 830000 x^{319/985}
y = 1 x^{3/2}
United States

Plate 2

Total Tons of Freight carried one mile per mile of line.

800000
700000
600000
500000
400000
300000

Group I

$k = \frac{1}{(10500)^{\frac{5}{2}}}$

Population

Millions

4 5 6

Plate 3.

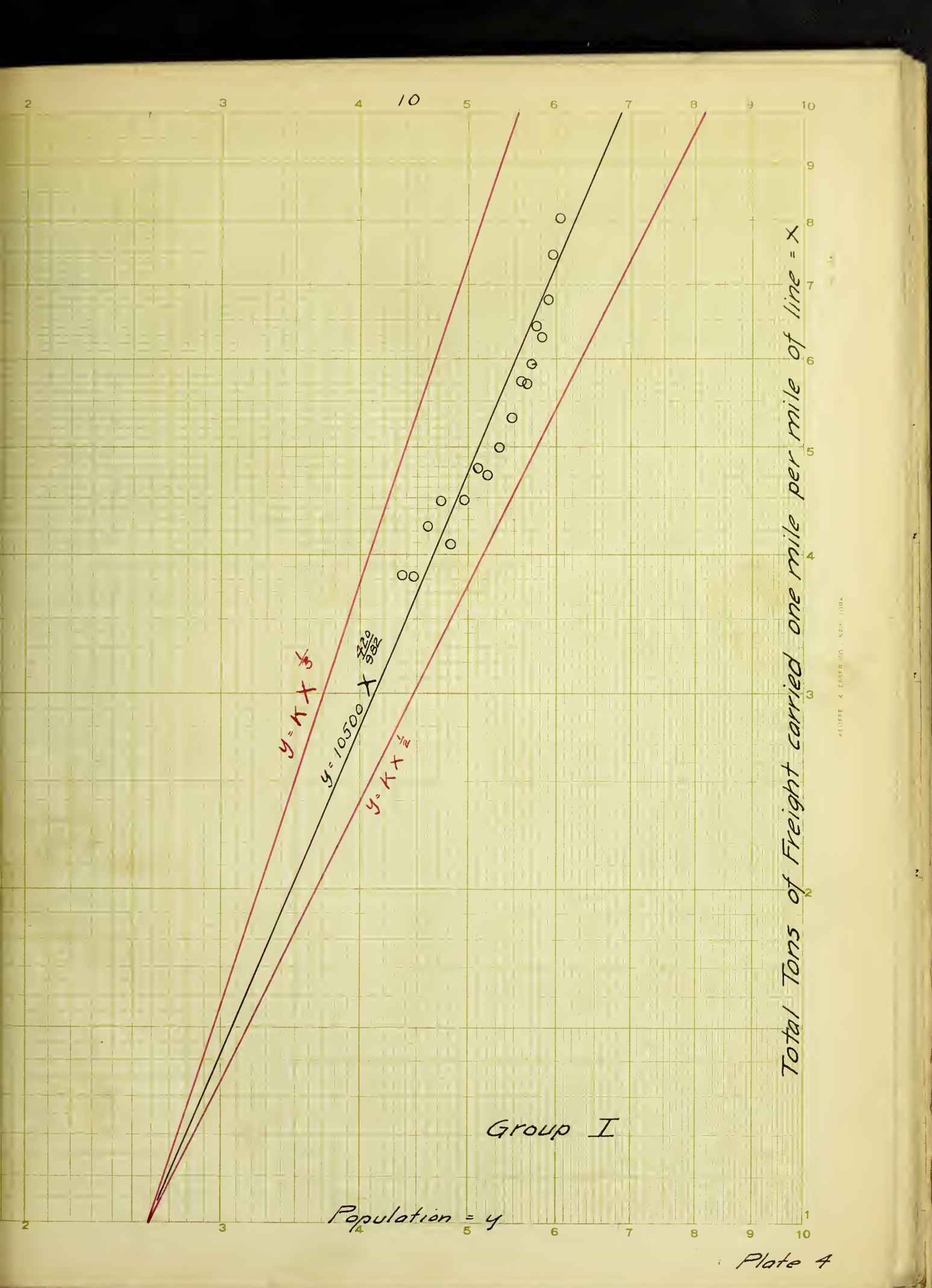

10
y = K X 3/5
y = 10500 X 220/982
y = K X 1/2
Total Tons of Freight carried one mile per mile of line = X
Group I
Population = y

Plate 4

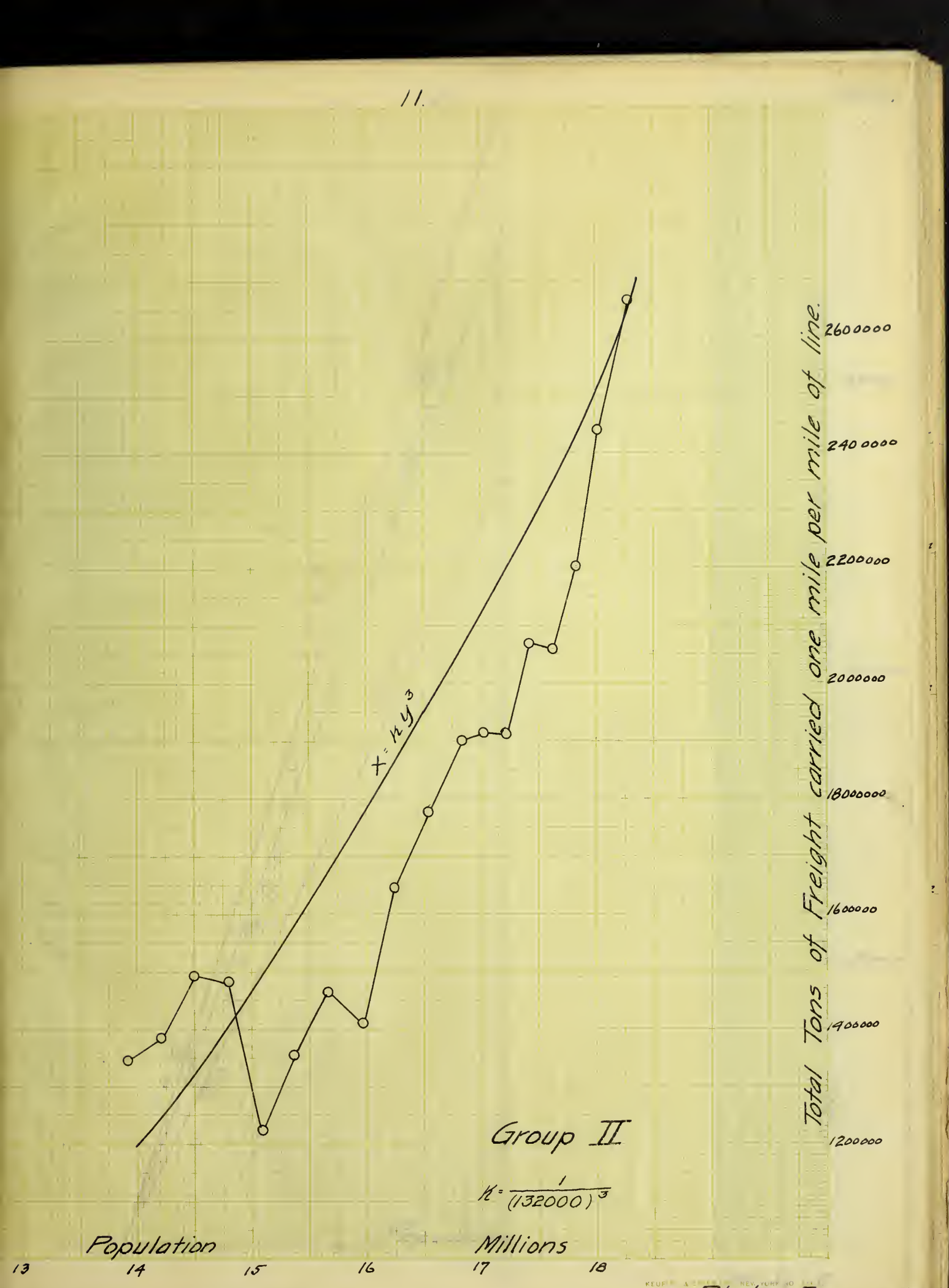
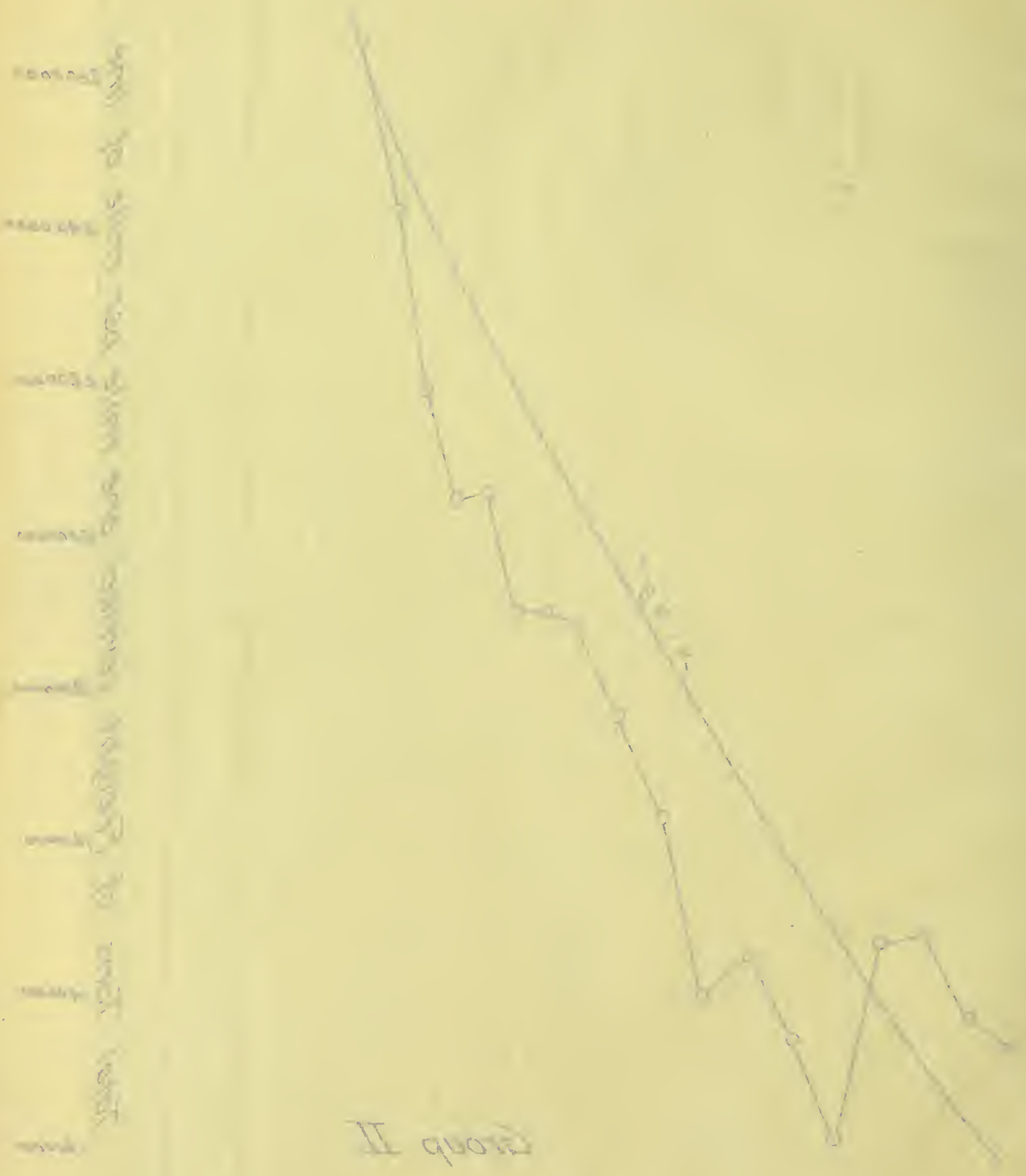

Total Tons of Freight carried one mile per mile of line.
2600000
2400000
2200000
2000000
1800000
1600000
1400000
1200000
$x = ky^3$
Group II
$k = \frac{1}{(132000)^3}$
Population
Millions
13
14
15
16
17
18

Plate 5.



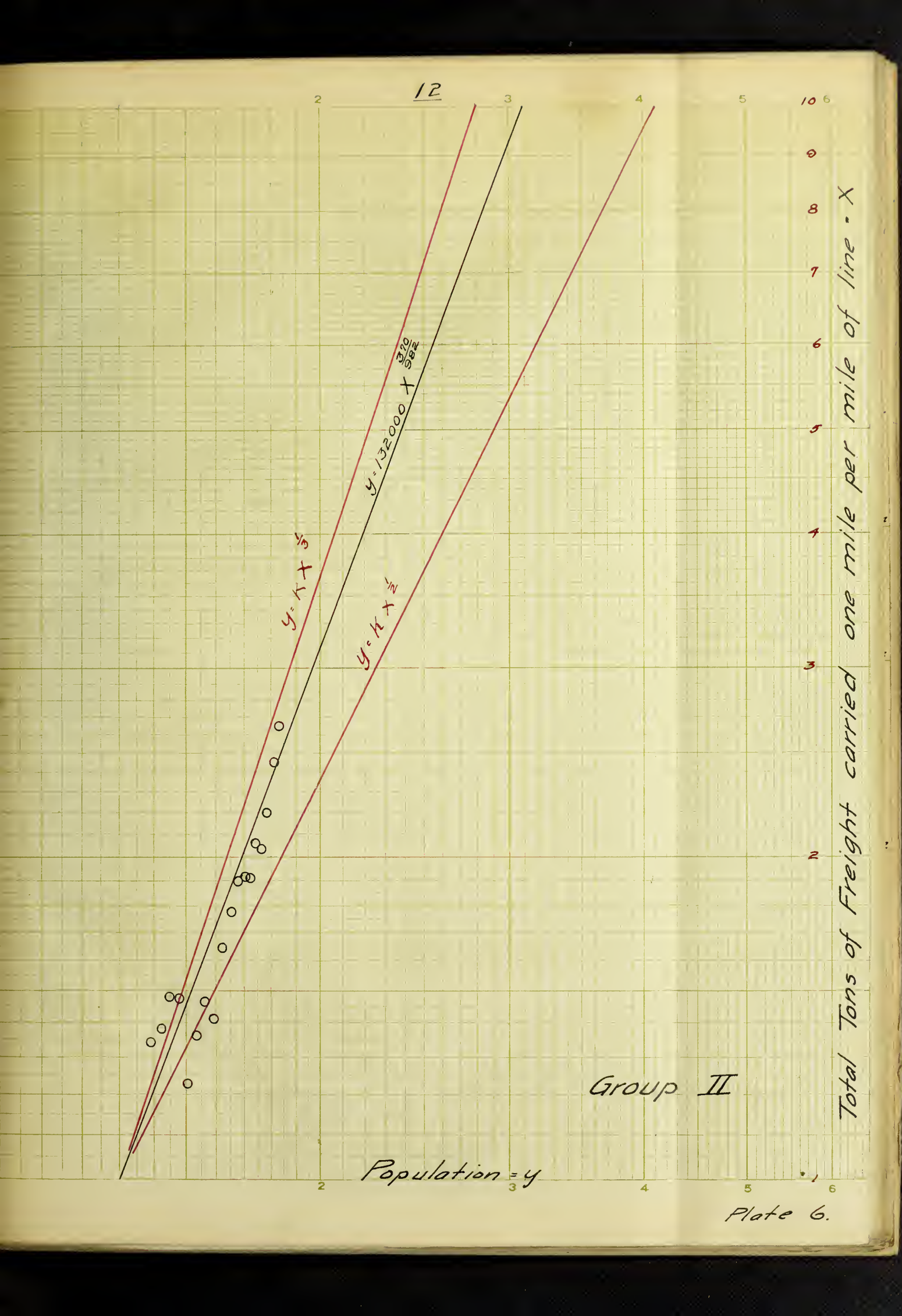

y = 132000 X 370/382
y = K X 1/3
y = K X 1/2
Total Tons of Freight carried one mile per mile of line = X
Population = y
Group II

Plate 6.

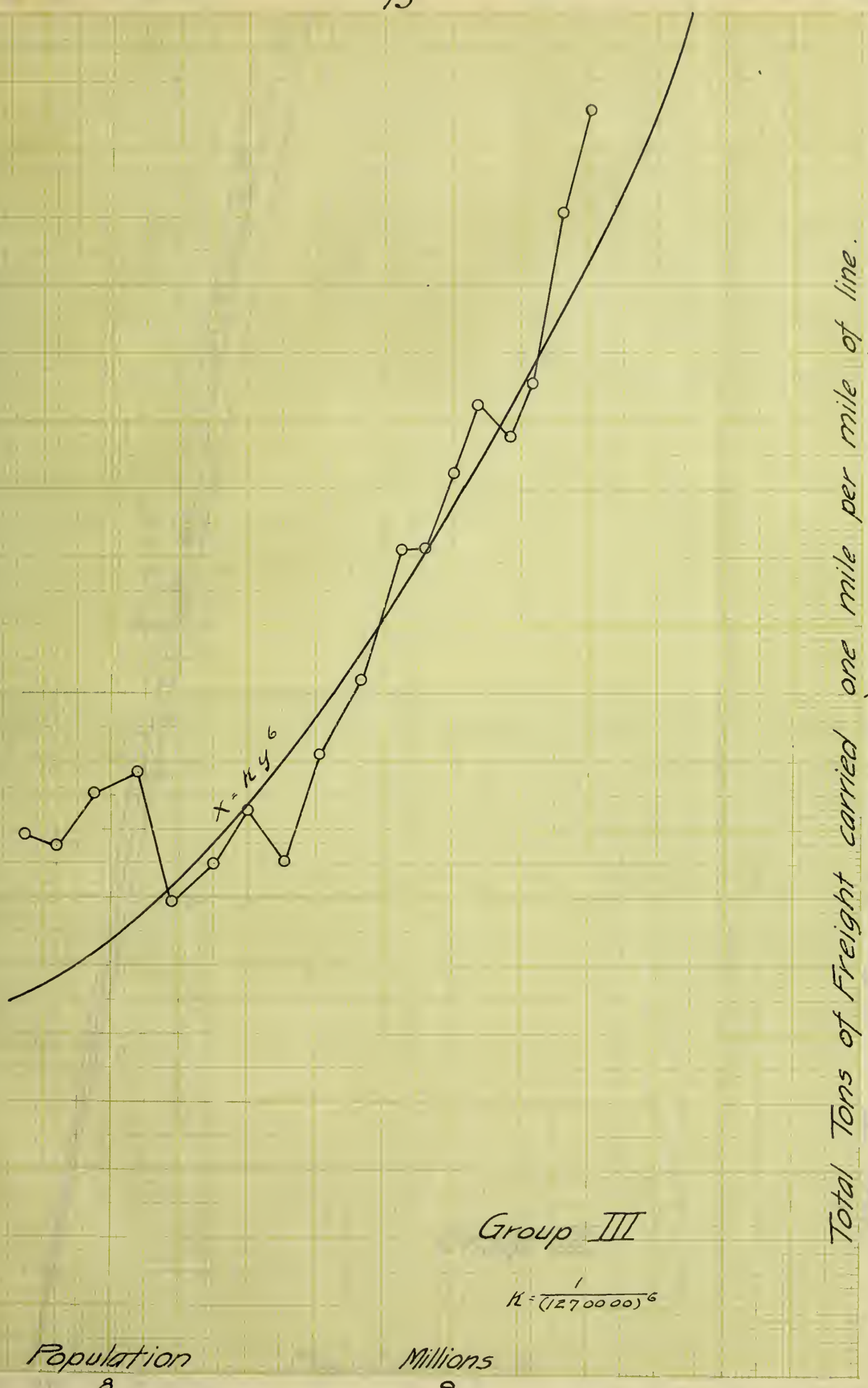

200000
150000
100000
50000
Total Tons of Freight carried one mile per mile of line.
$X = Ky^6$
Group III
$K = \frac{1}{(12700000)^6}$
Population
8
Millions
9

Plate 7.

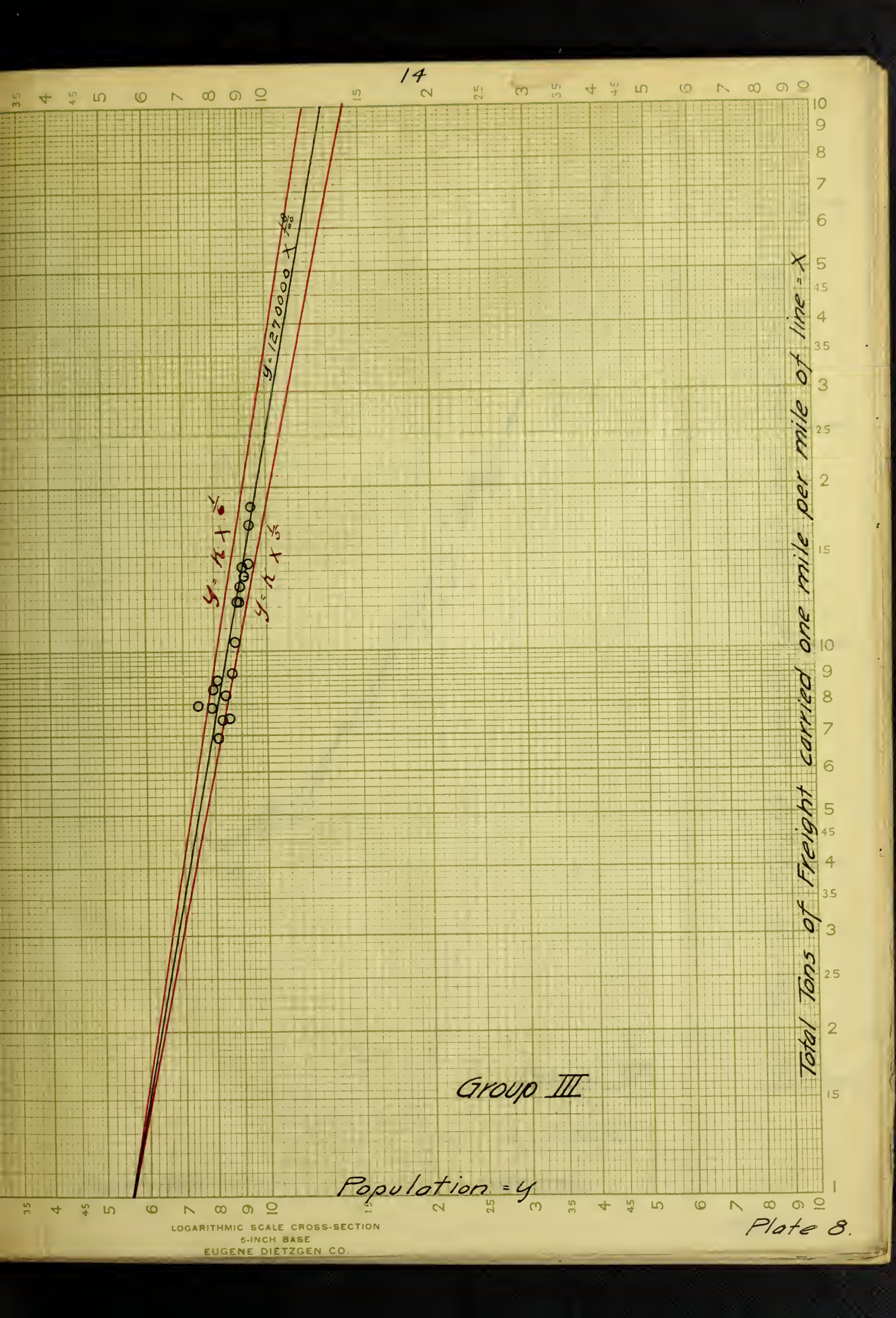
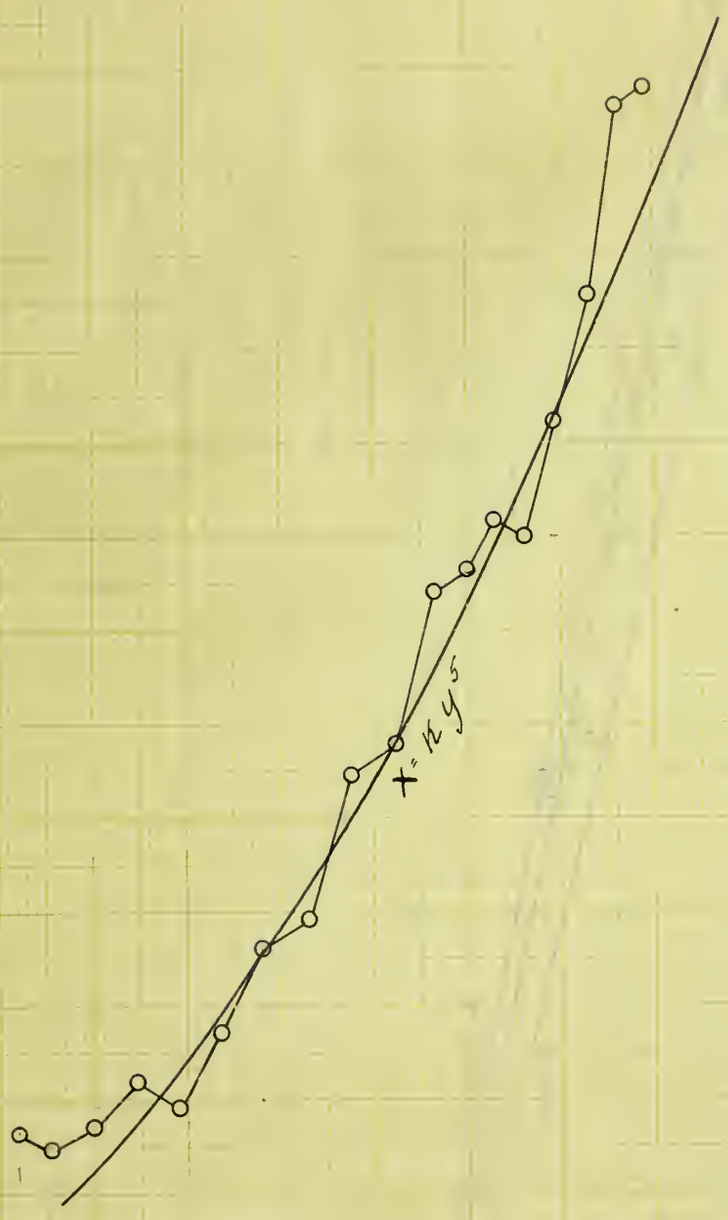

y = 1270000 x 18/20
y = 1.4 x 1.4
y = 1.4 x 3/5
Total Tons of Freight Carried one mile per mile of line = X
Group III
Population = y
LOGARITHMIC SCALE CROSS-SECTION
5-INCH BASE
EUGENE DIETZGEN CO.

Plate 8.



900000

700 000

500000

300000

100000

Total Tons of Freight carried one mile per mile of line.

Group IV

$$\frac{1}{k \cdot (445\,000)^5}$$

Population

5 6 7

Millions.

Plate 9.

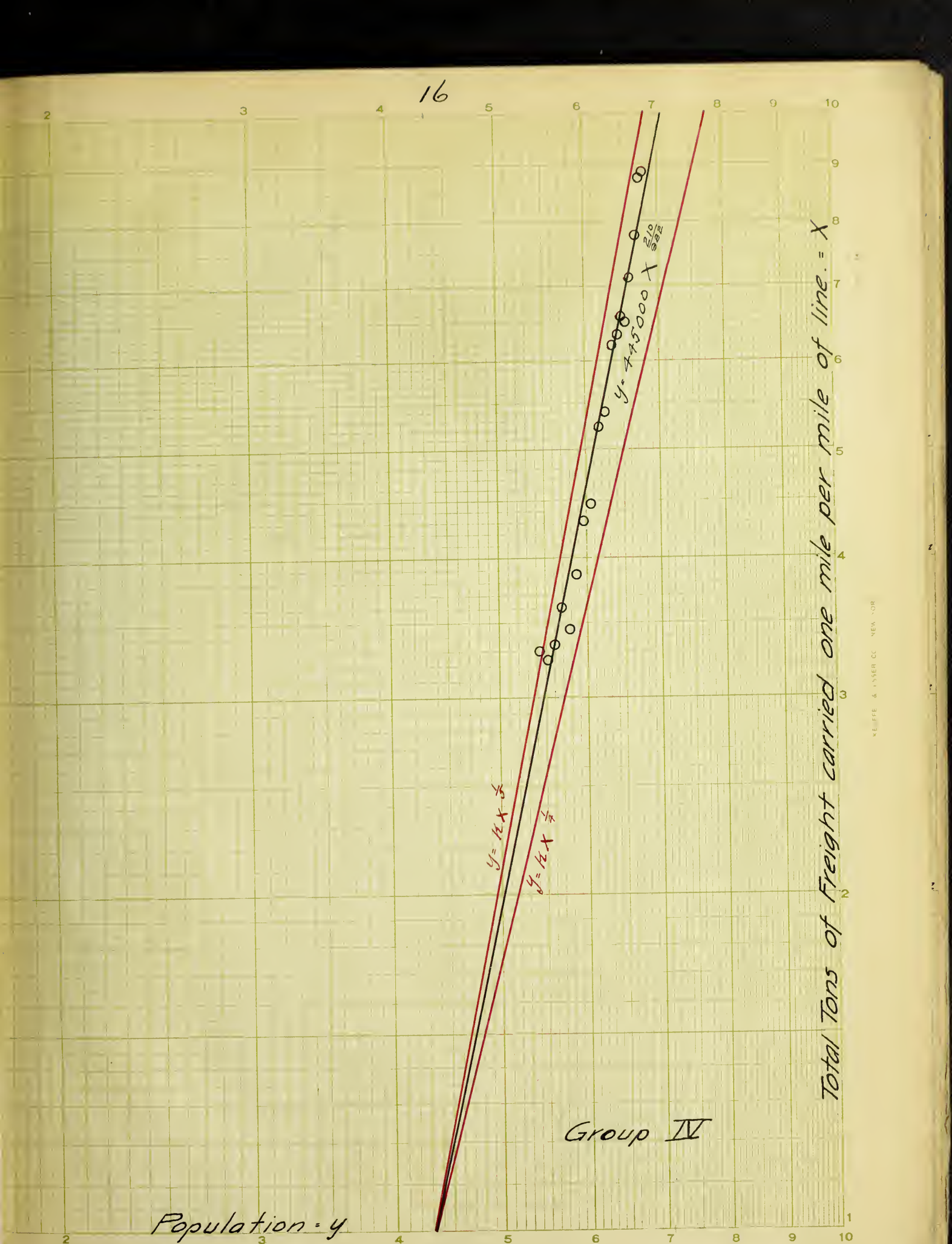
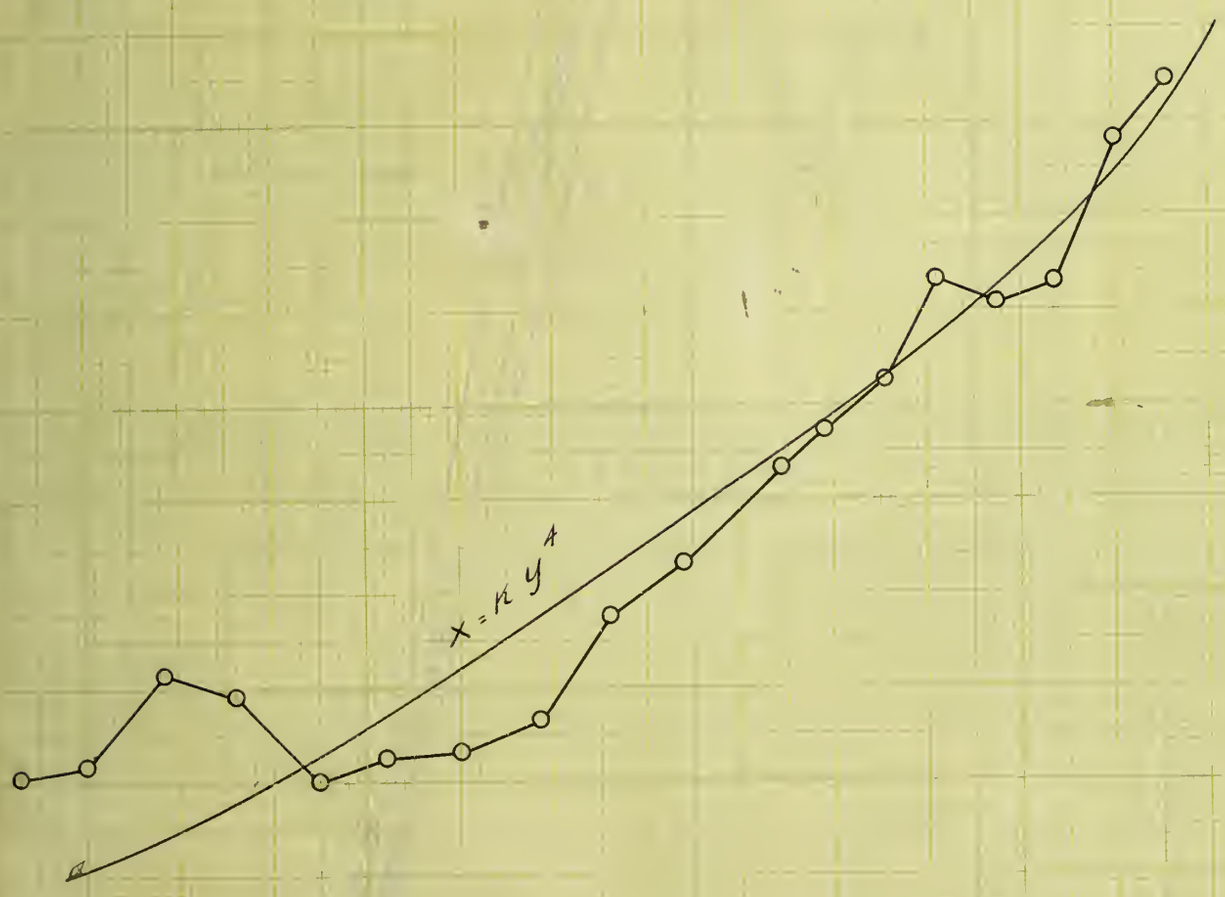

Total Tons of Freight carried one mile per mile of line. = X
Population = y
y = 445000 X 2.10/3812
y = 4x + 5
y = 4x + 5
Group IV

Plate 10.



Total Tons of Freight carried one mile per mile of line.

800000

600000

400000

200 000

Group V

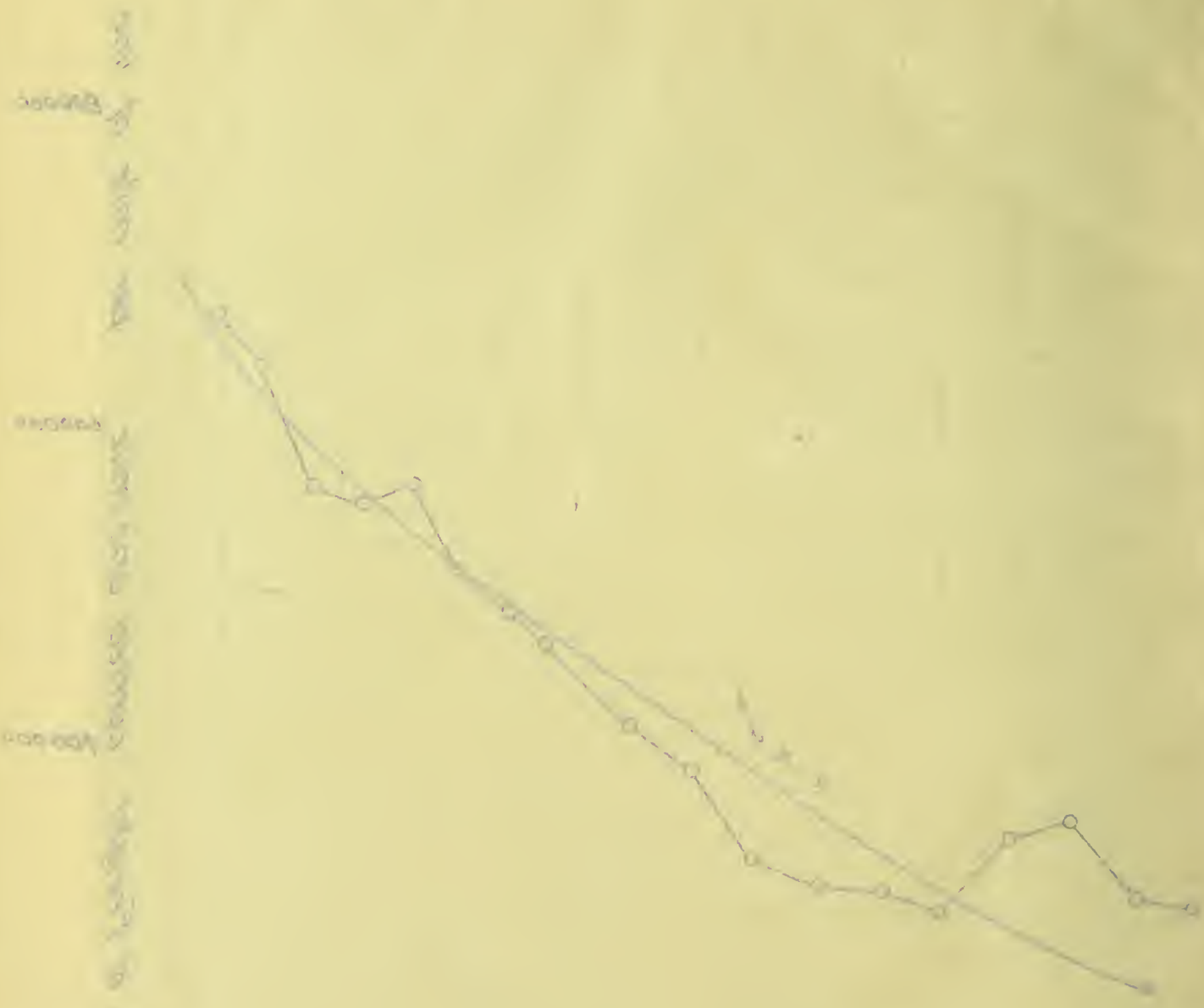
$k = \frac{1}{(3920000)^4}$

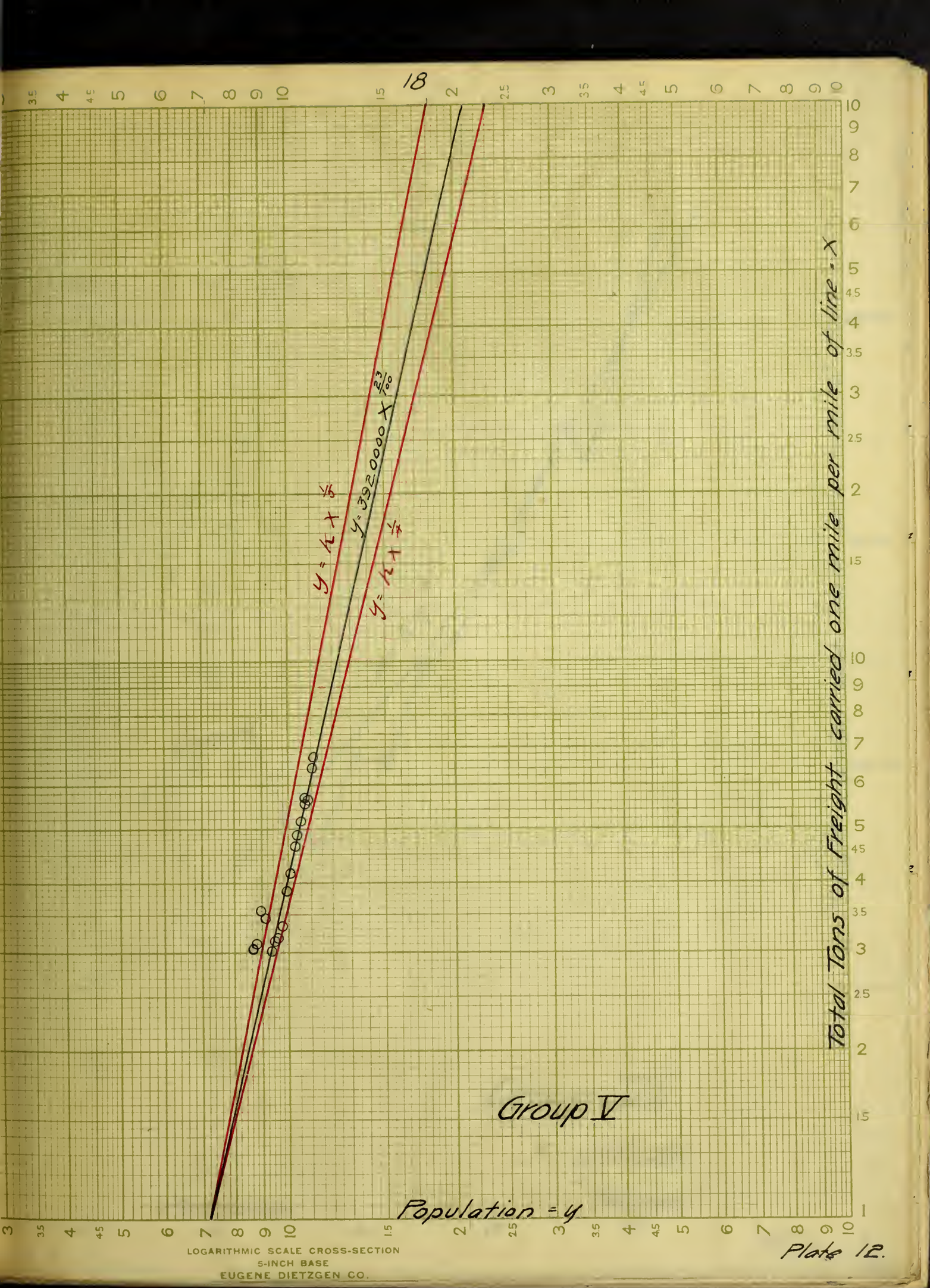
Population

Millions

9 10 11

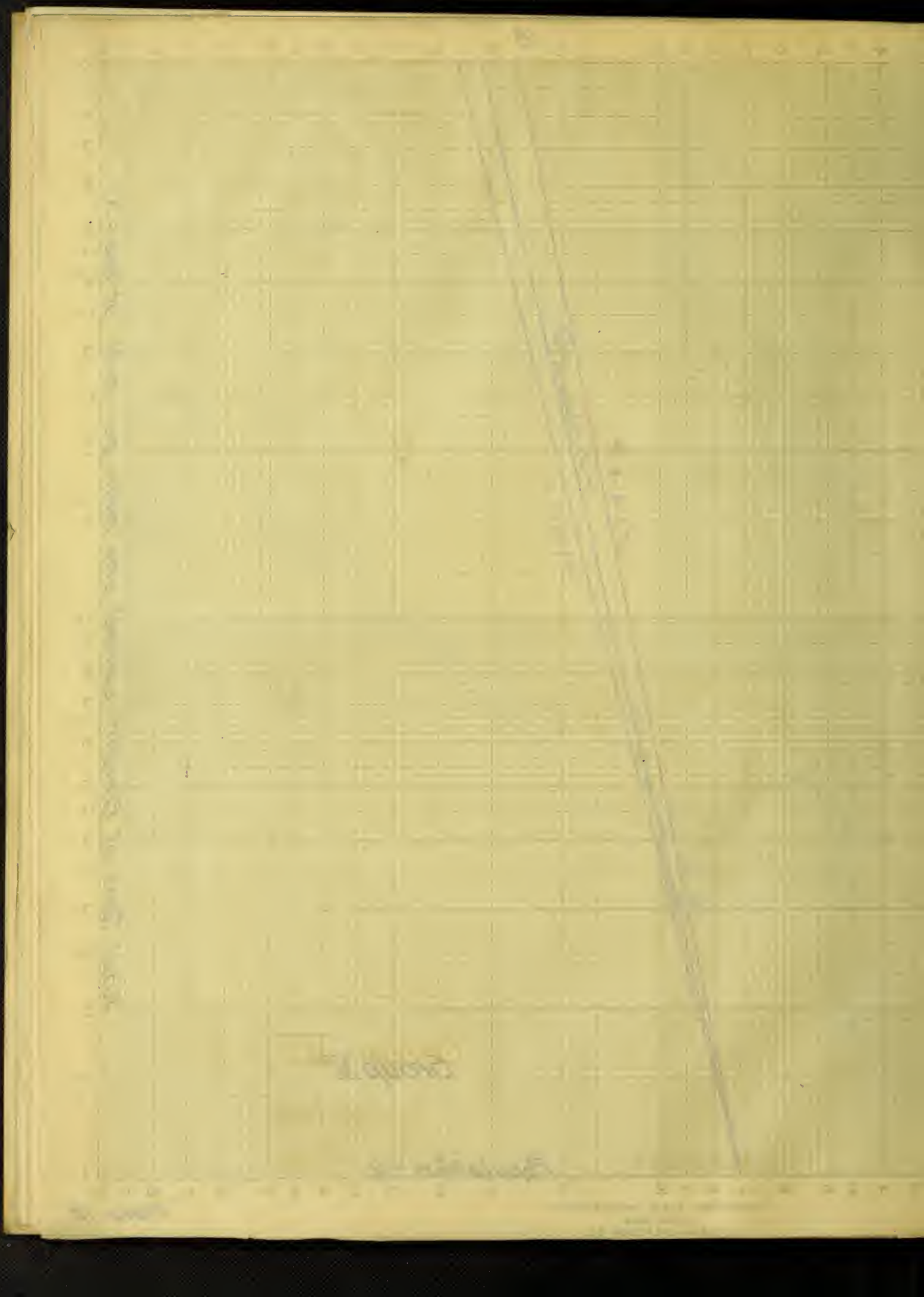
Plate 11.

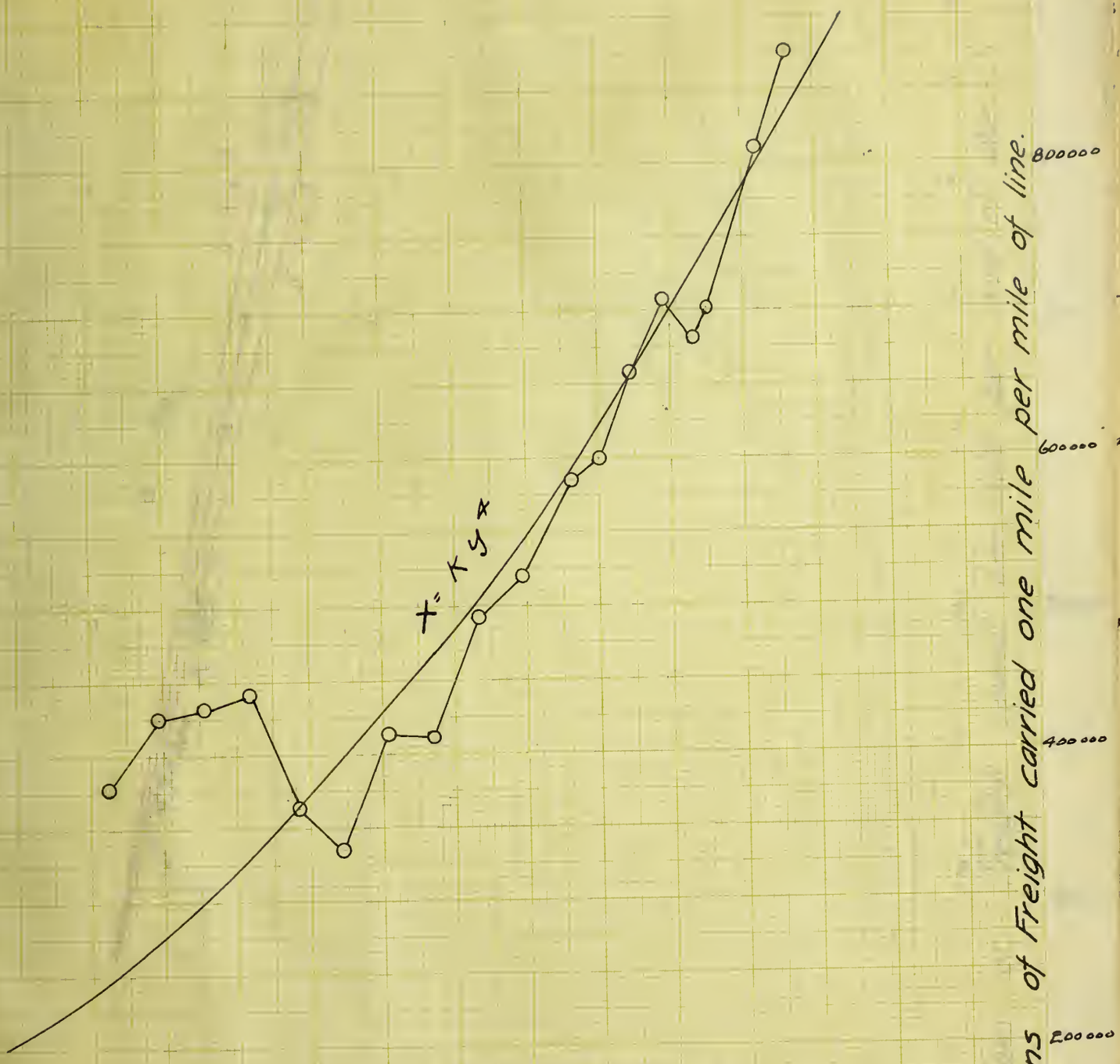




LOGARITHMIC SCALE CROSS-SECTION
5-INCH BASE
EUGENE DIETZGEN CO.

Plate 12.





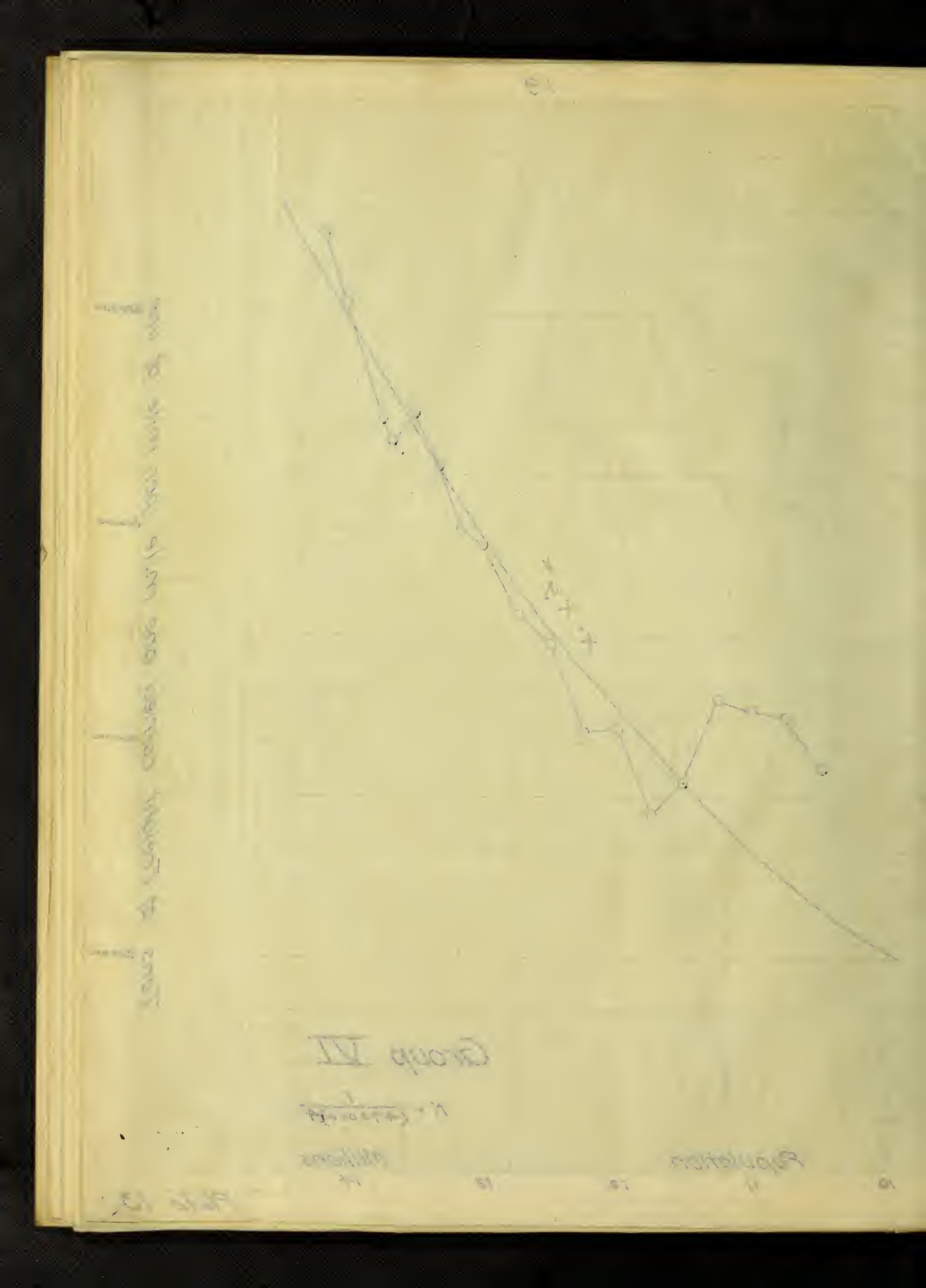
Group VI

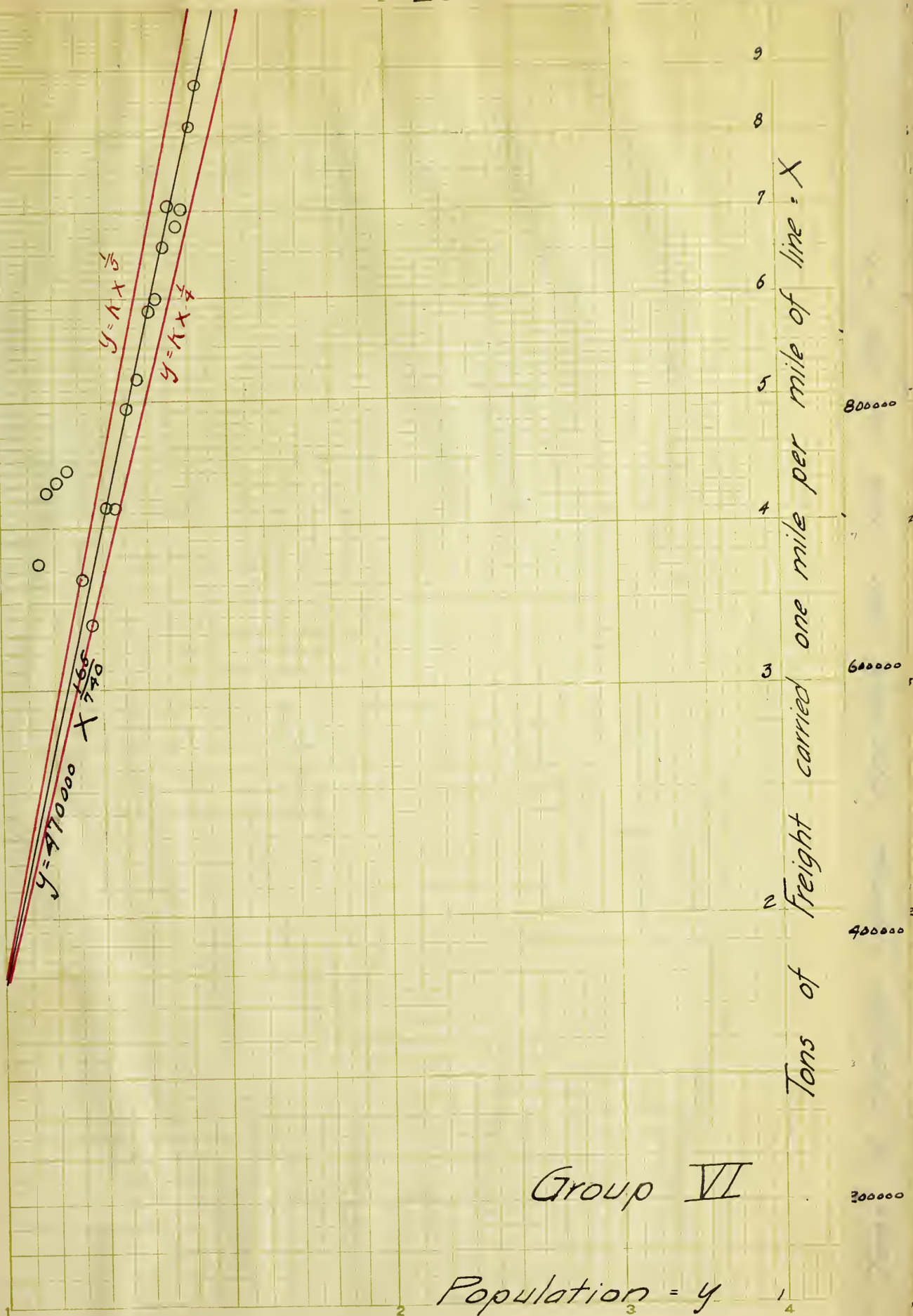
$$K = \frac{1}{(470000)^4}$$

Population — Millions

10 11 12 13 14

Plate 13.





Group VI

Plate 14

15.

Group VII

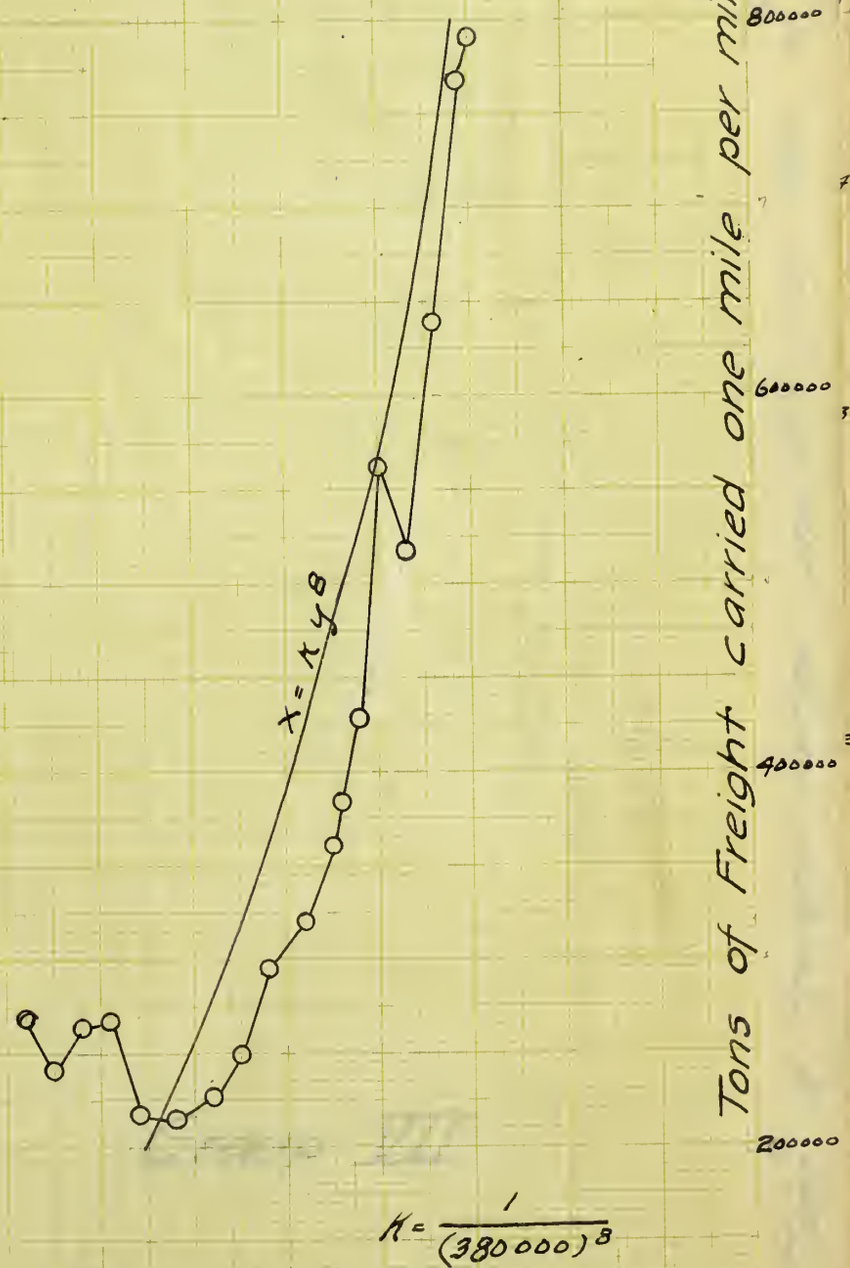
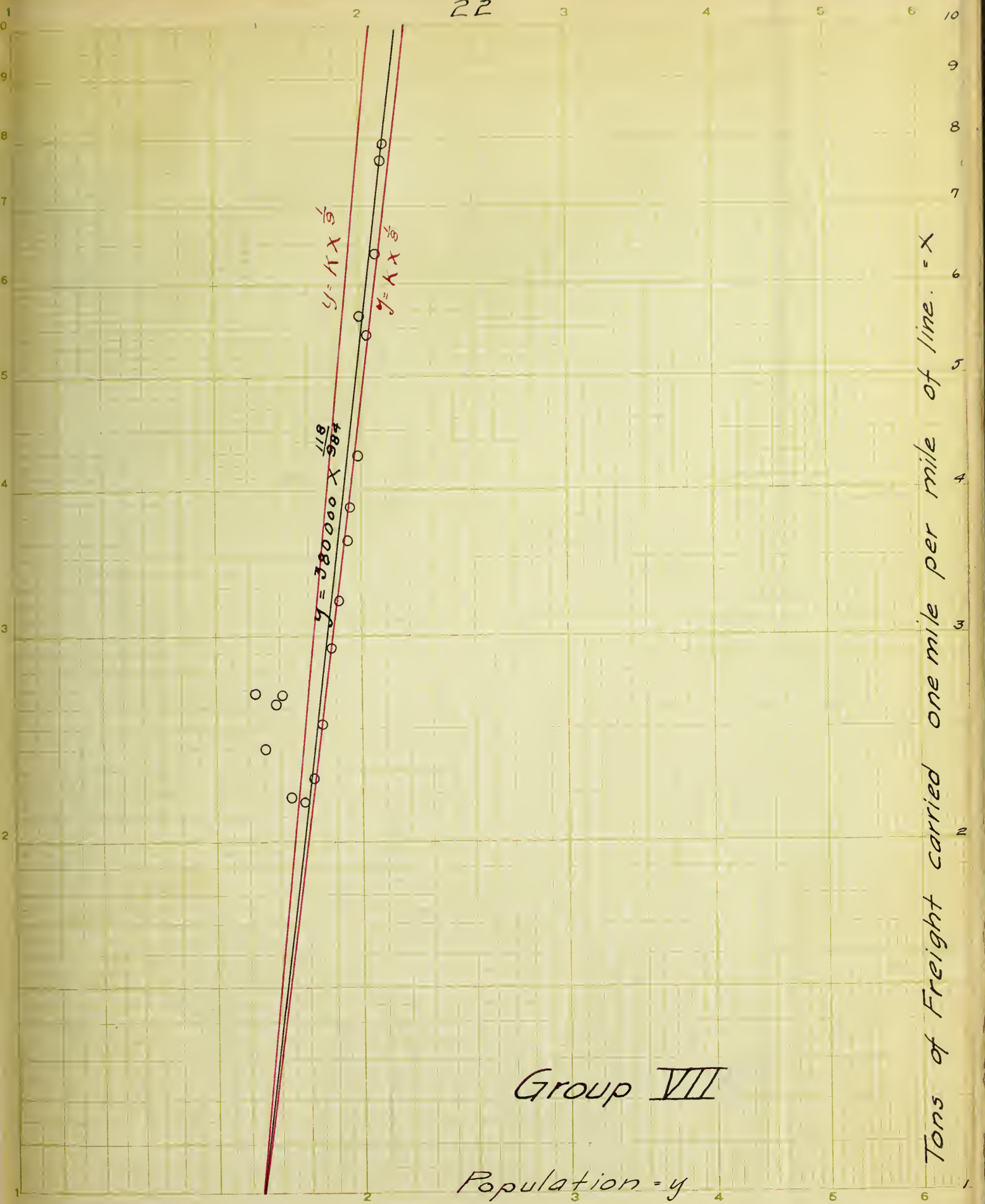


Plate 15.



Tons of Freight carried one mile per mile of line. = x

Group VII

Population = y

Plate 16

500 000

400 000

300 000

200 000

Total Tons of Freight carried one mile per mile of line.

Group VIII

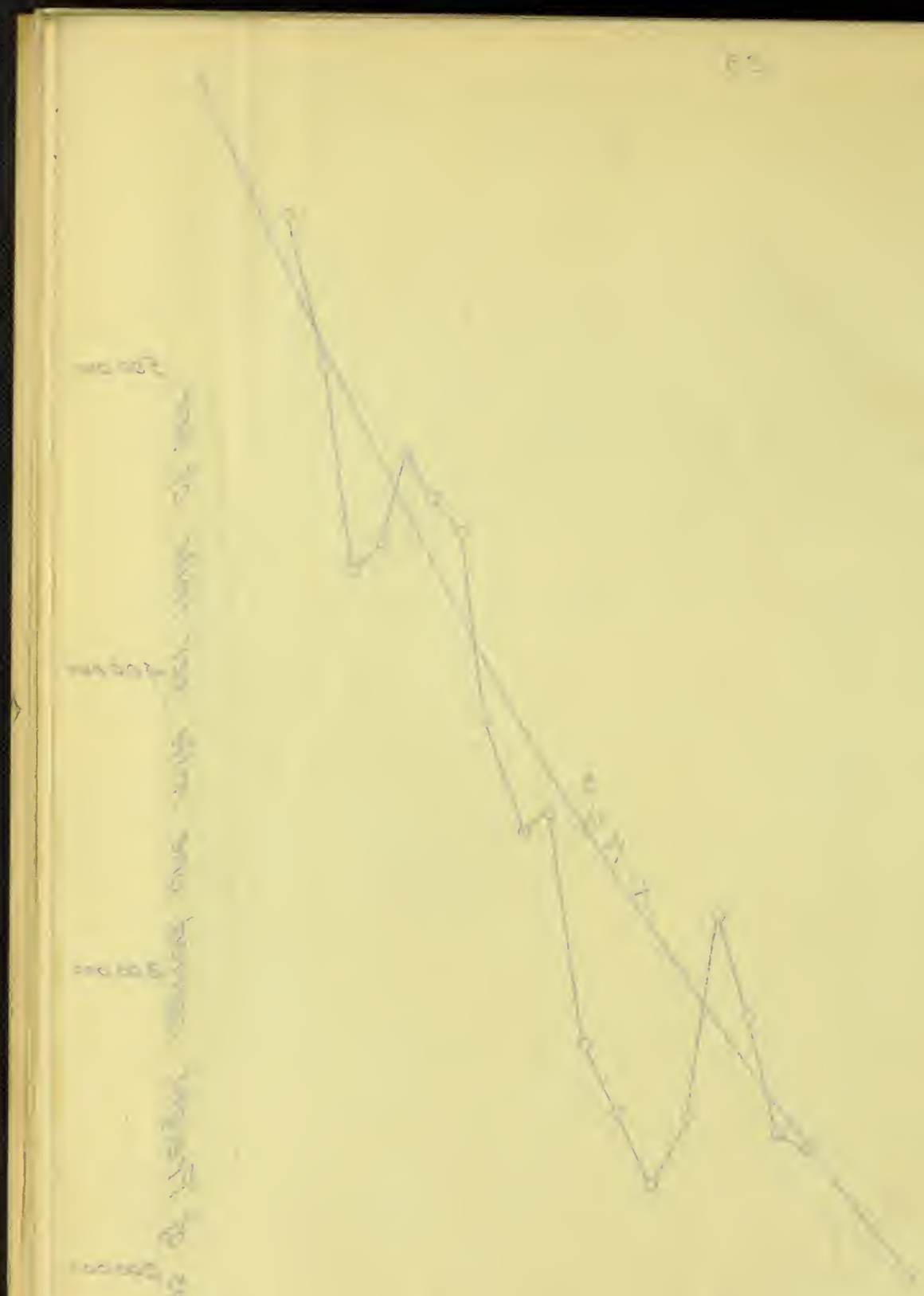
$k = \frac{1}{(75000)^3}$

Population

Millions.

4.0 5.0 6.0

Plate 17



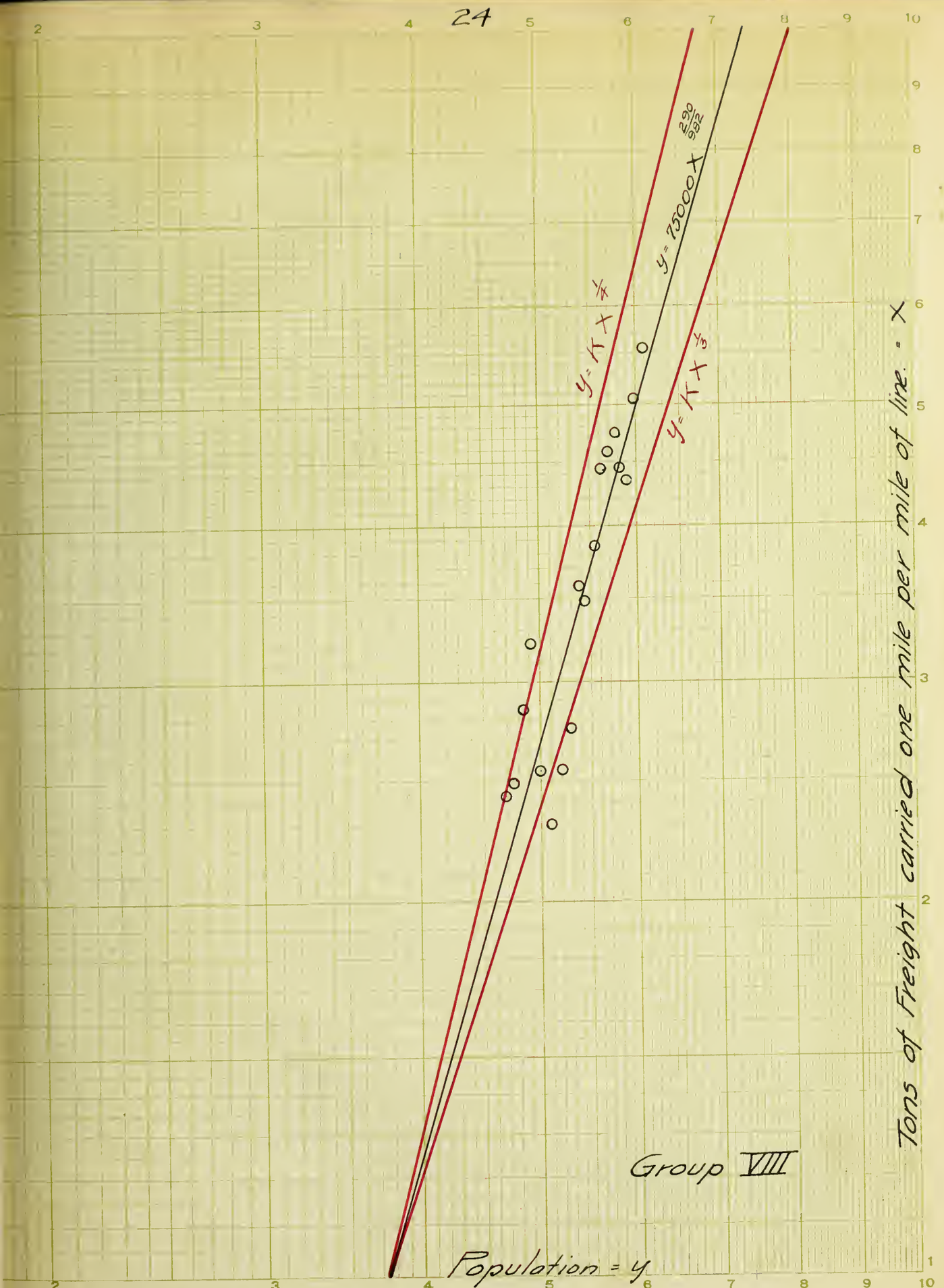
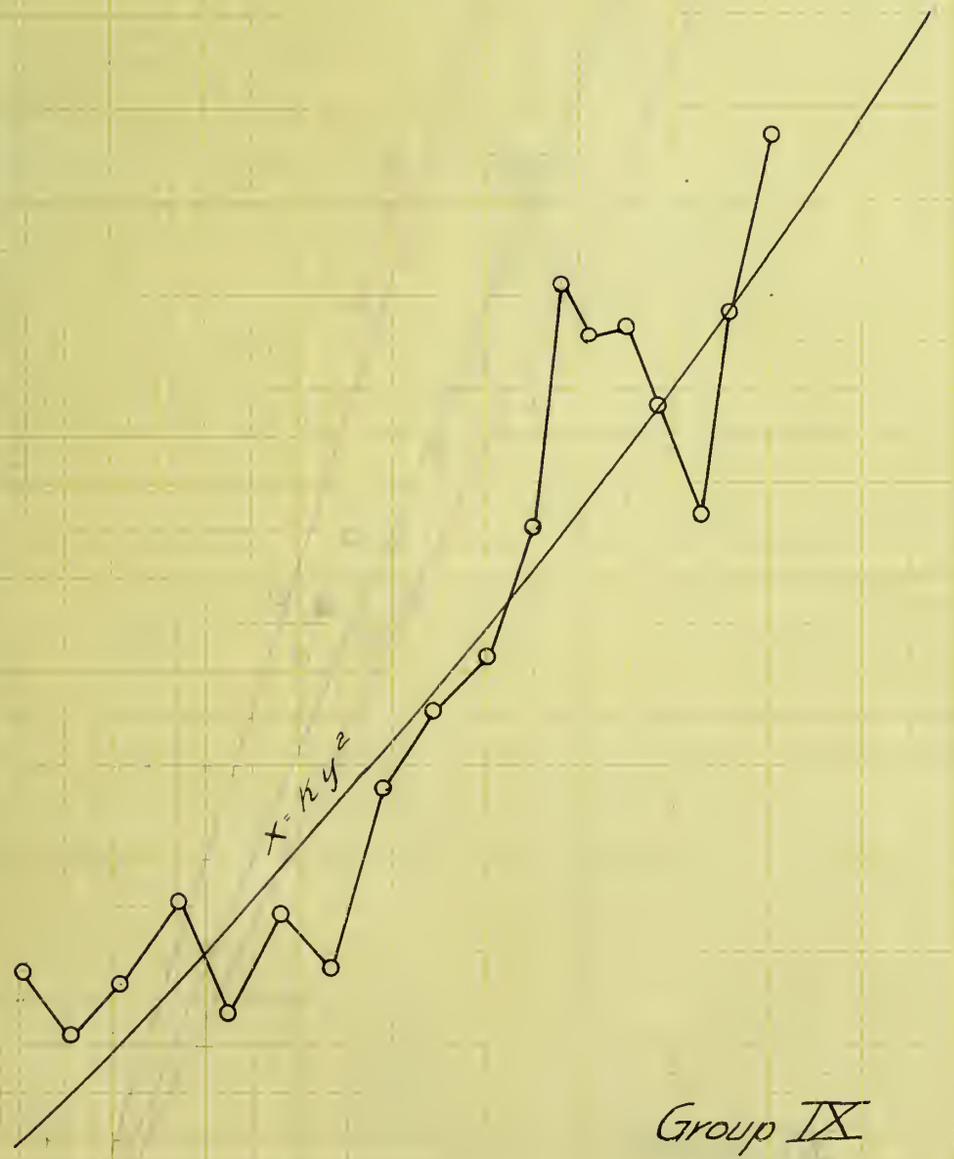

y = 75000 x^{290/932}
y = K x^{1/2}
y = K x^{1/3}
Tons of Freight carried one mile per mile of line. = X
Population = y
Group VIII

Plate 18



600 000

400 000

200 000

Total Tons of Freight carried one mile per mile of line.

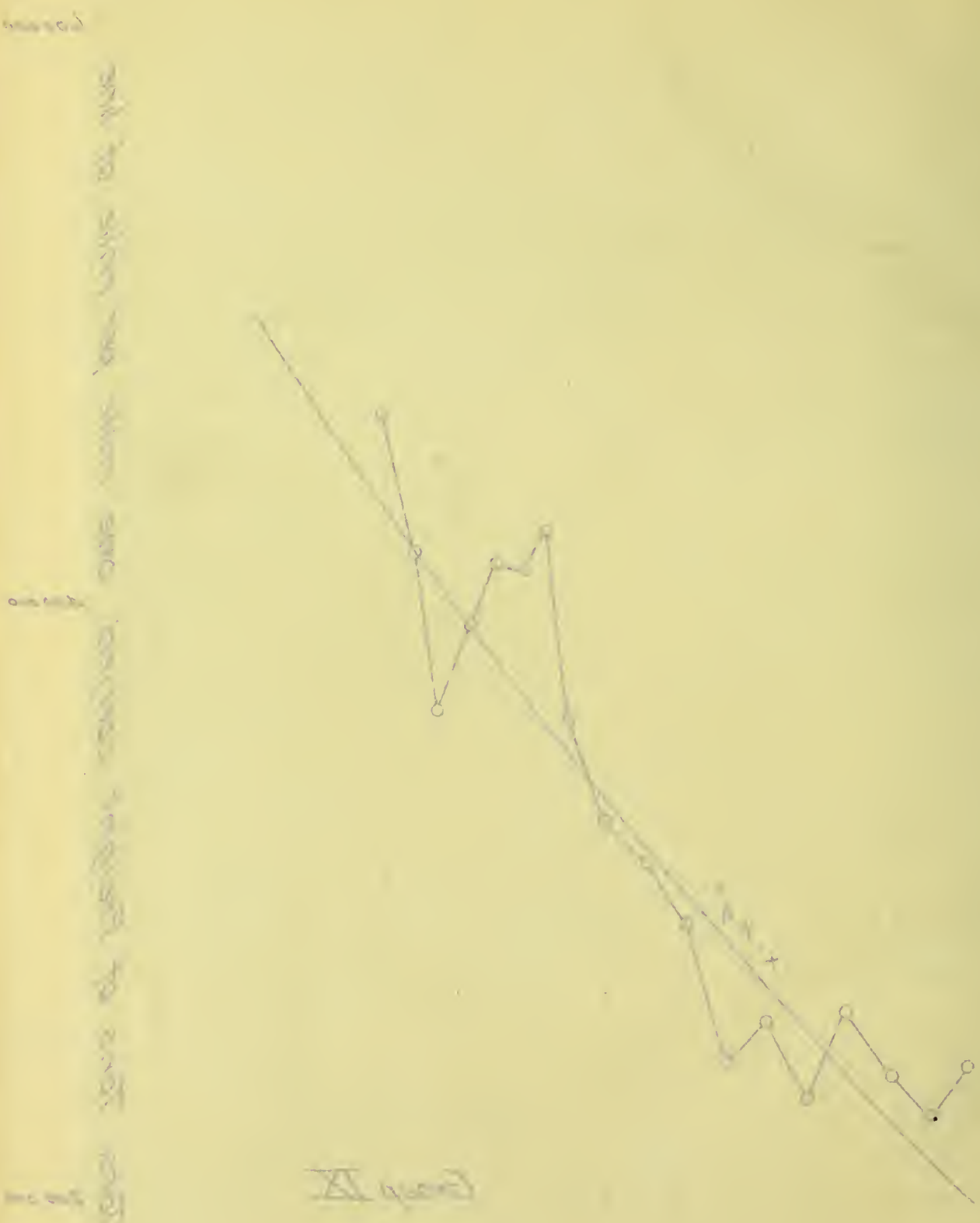
Group IX

$k = \frac{1}{24000^2}$

Population Millions

3 4 5

Plate 19



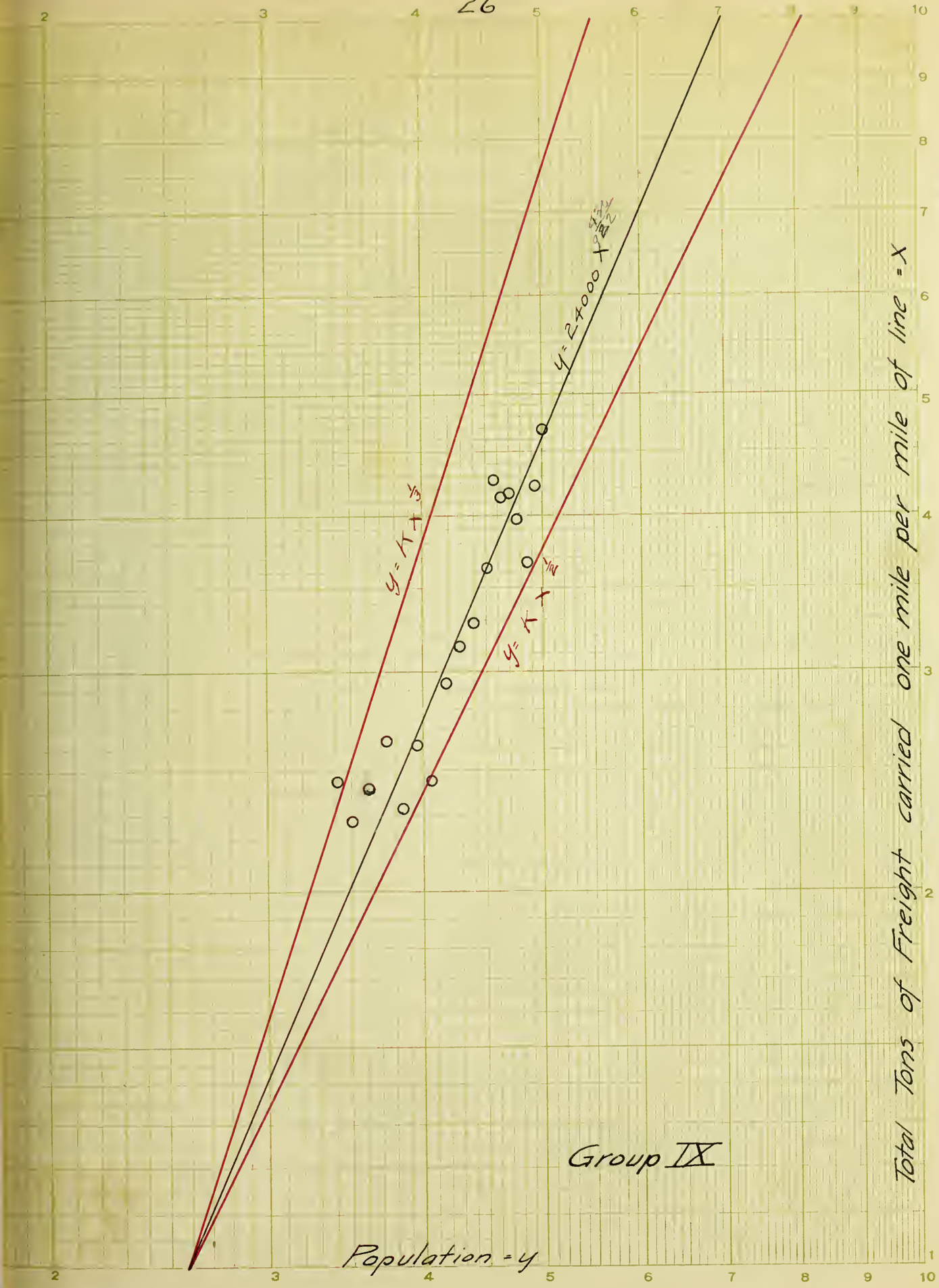

y = 24000 x^{4/3}
y = 1.1 x^{1/3}
y = 1 x^{1/2}
Total Tons of Freight carried one mile per mile of line = X
Population = y
Group IX

Plate 20.

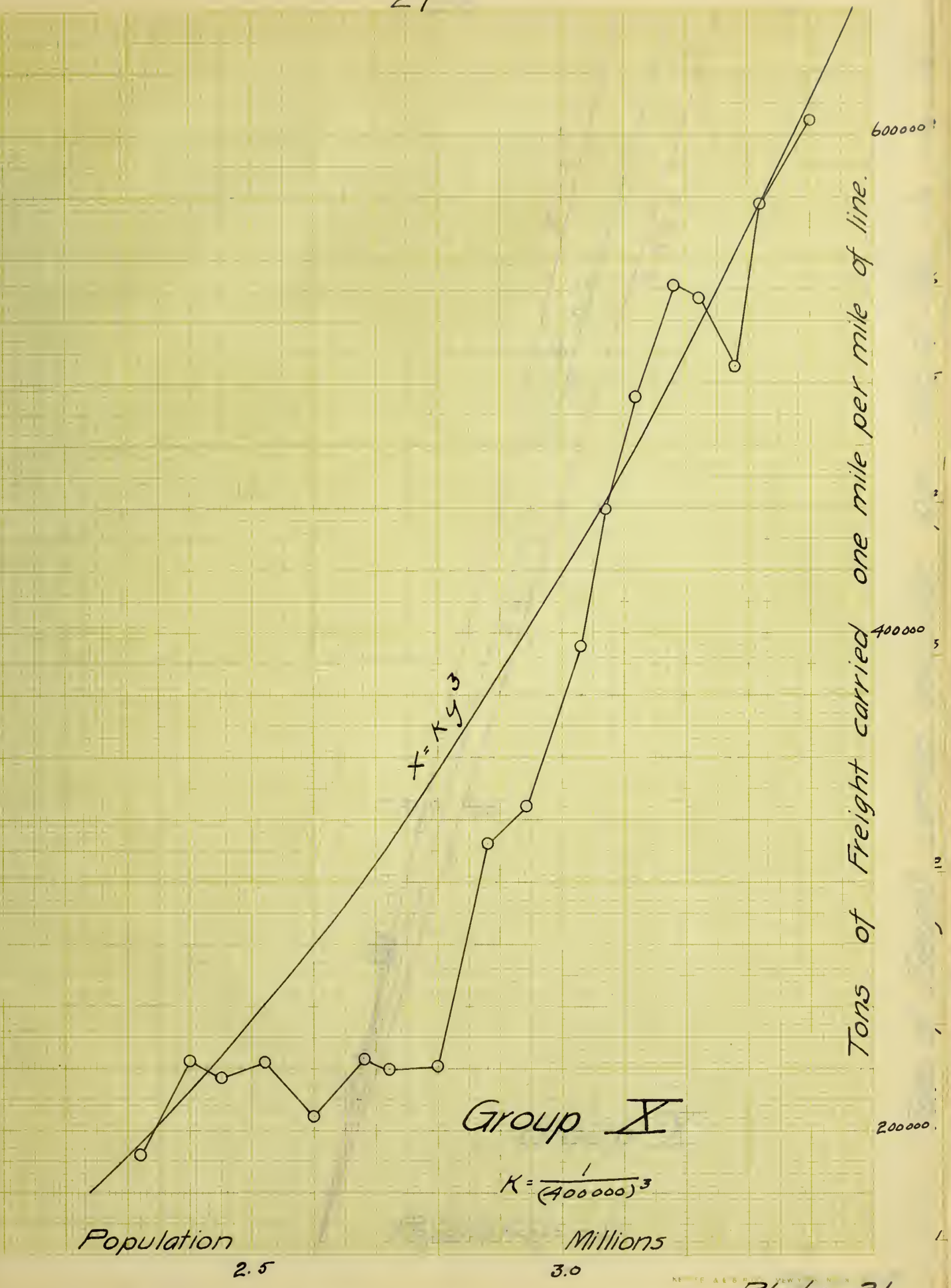
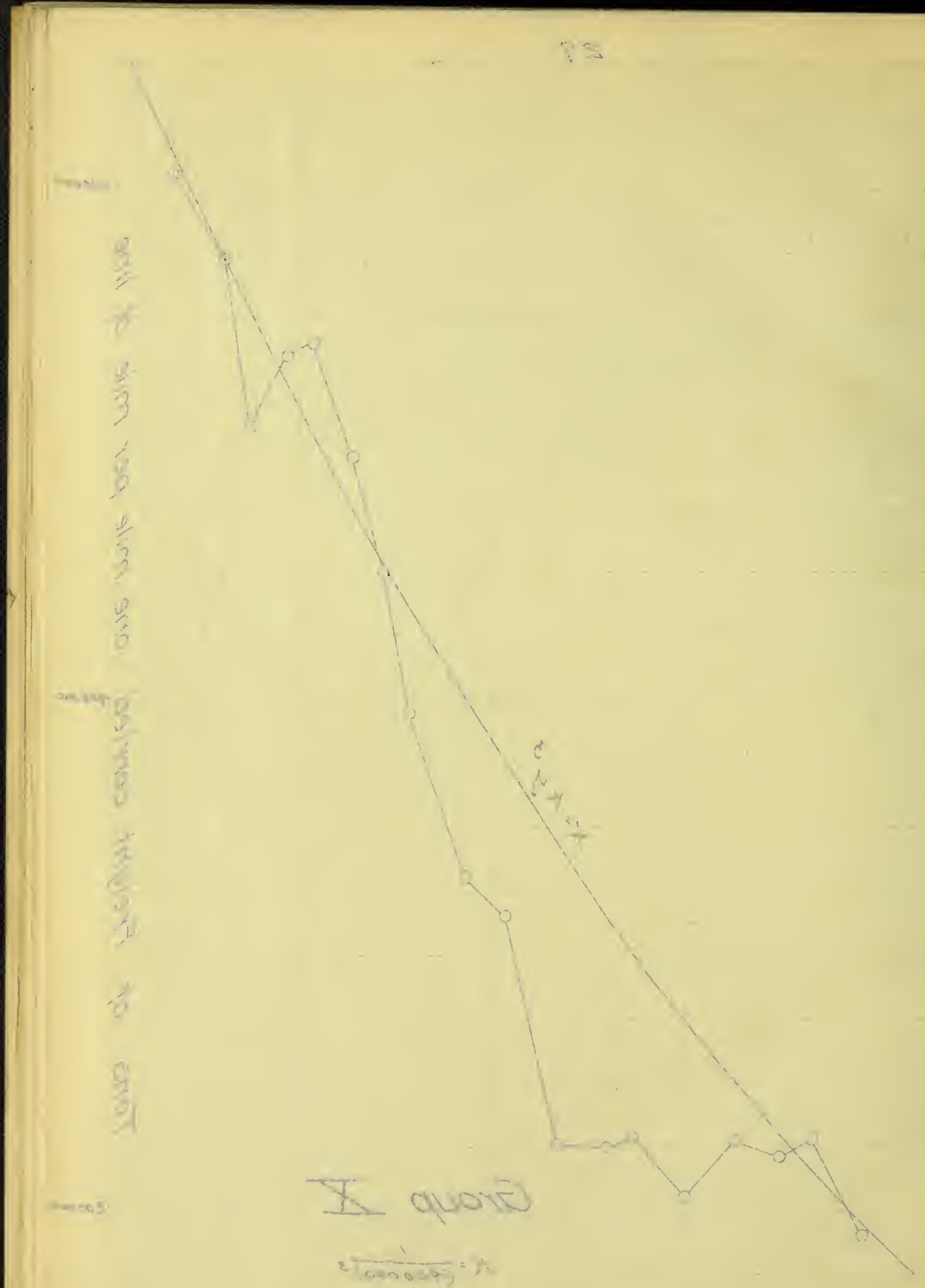

600000
400000
200000
Tons of Freight carried one mile per mile of line.
$x = ky^3$
Group X
$K = \frac{1}{(400000)^3}$
Population
Millions
2.5
3.0

Plate 21.



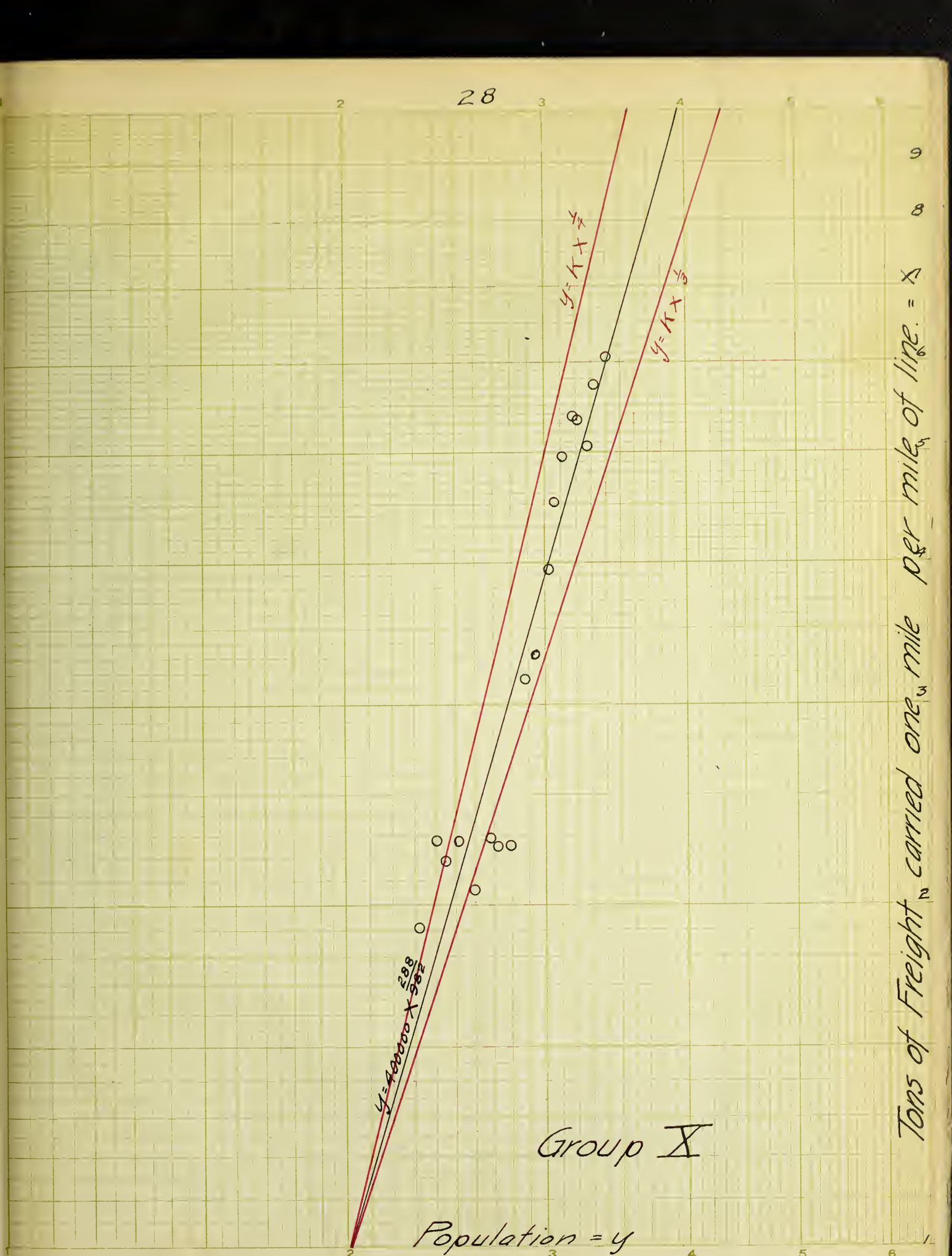

y = 400000 x^{288/382}
y = K x^{3/4}
y = K x^{1/3}
Tons of Freight carried one mile per mile of line. = x
Population = y
Group X

Plate 22

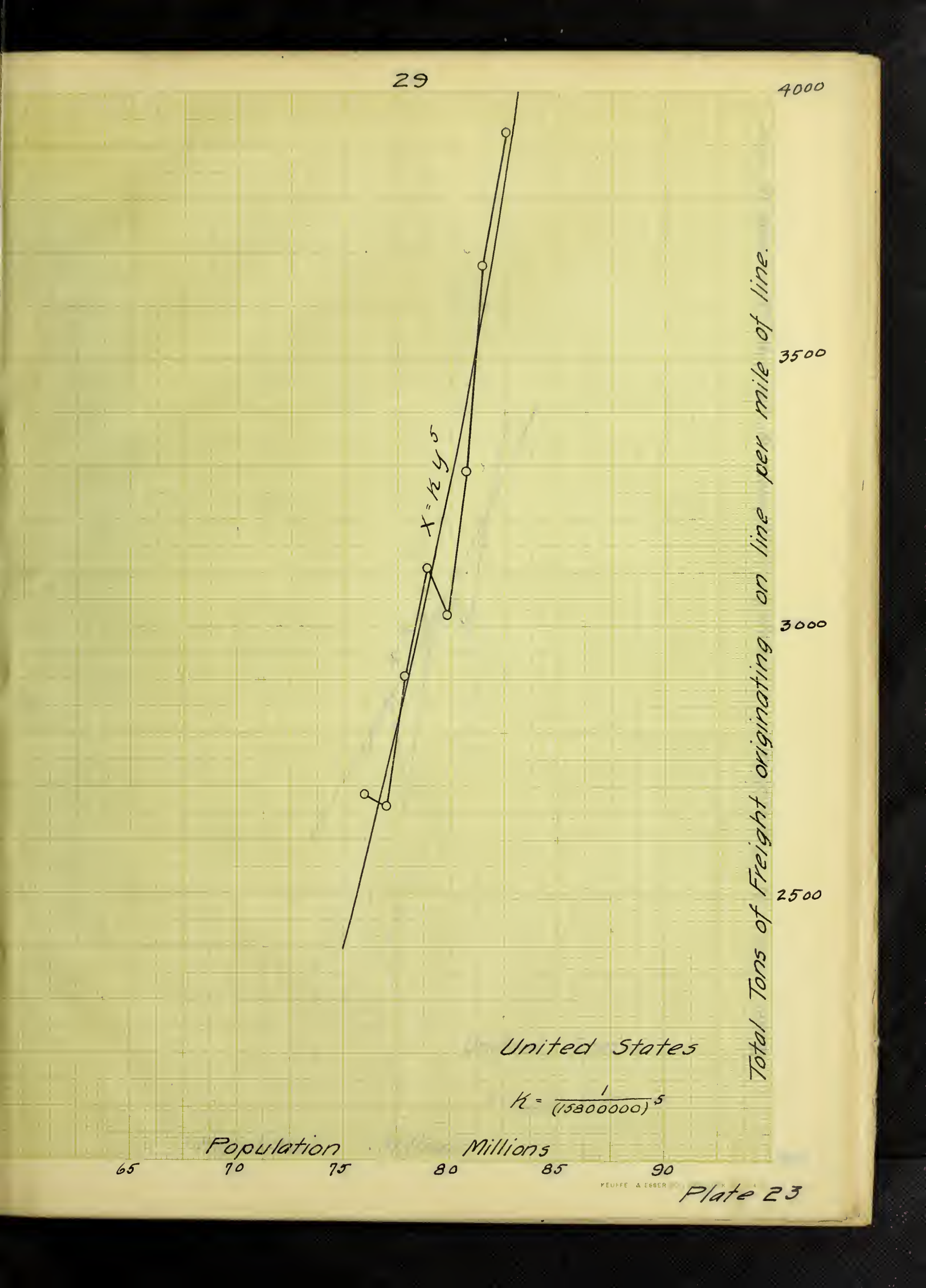
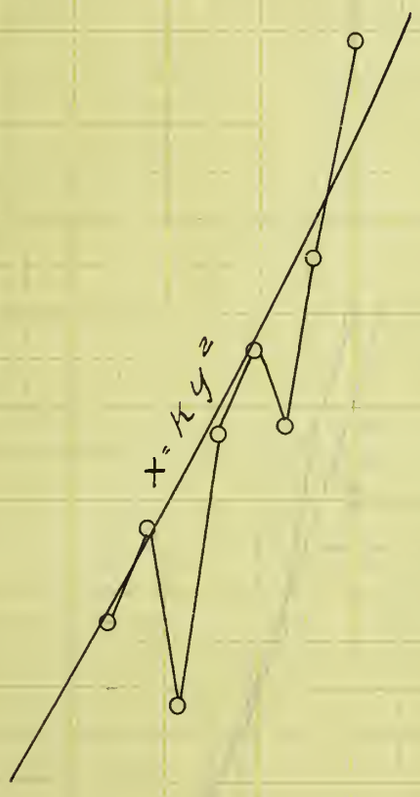

4000
3500
3000
2500
Total Tons of Freight originating on line per mile of line.
$x = ky^5$
United States
$k = \frac{1}{(15800000)^5}$
Population
Millions
65
70
75
80
85
90
KEUFFEL & ESSER

Plate 23



400

300

200

Total Tons of Agricultural Products originating on line per mile of line

United States.

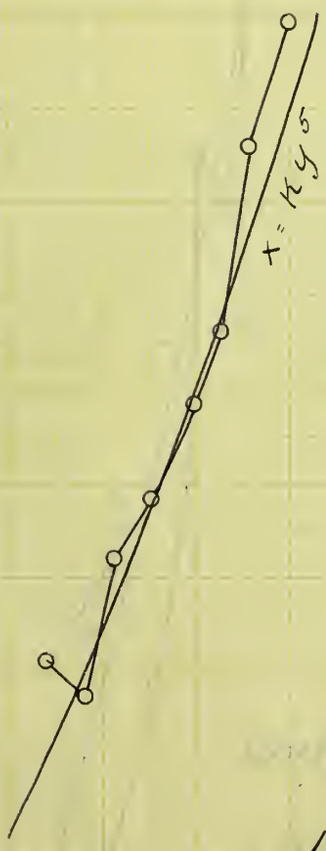
$K = \frac{1}{(4550000)^2}$

Population Millions

70 75 80 85 90

KEUFFEL & ESSER

Plate 24



3000

2000

1000

Total Tons of Mine Products originating on line per mile of line.

United States

$k = \frac{1}{(7200000)^5}$

Population

Millions

70 75 80 85 90

Plate 25

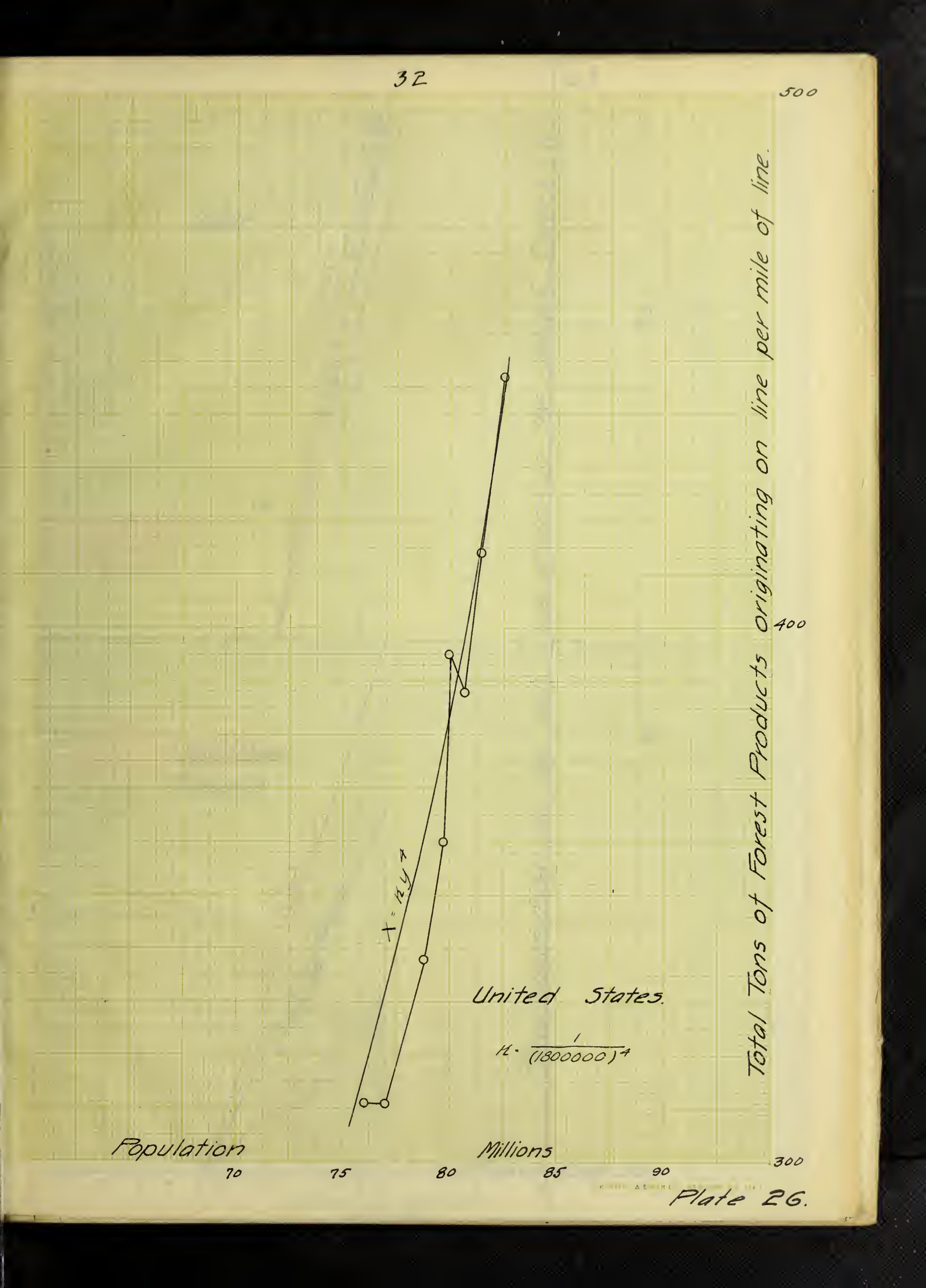

500
400
300
Total Tons of Forest Products originating on line per mile of line.
x = ky^4
United States.
k = 1/(1800000)^4
Population
Millions
70
75
80
85
90

Plate 26.

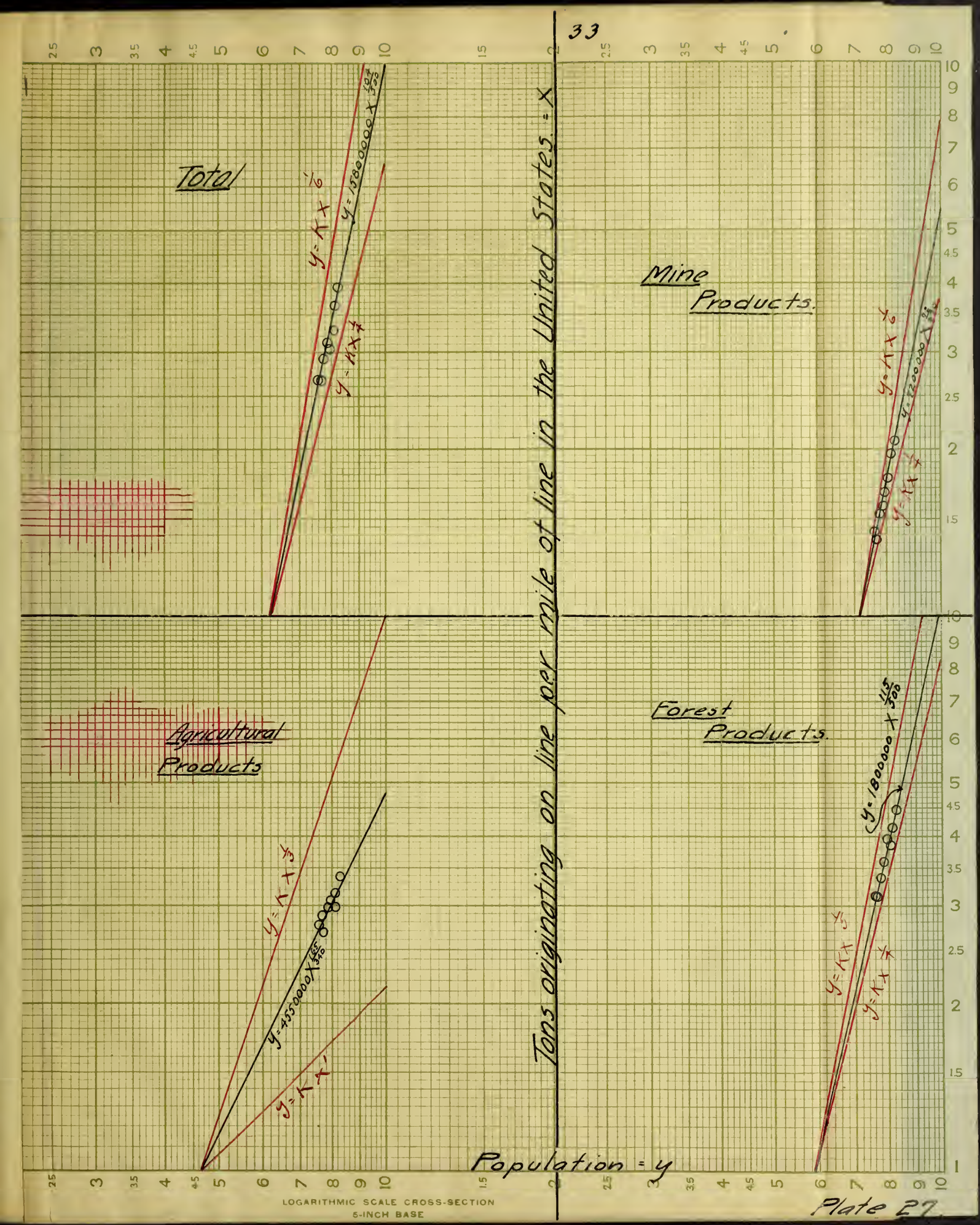

Total
Mine Products.
Agricultural Products
Forest Products.
Tons originating on line per mile of line in the United States = x
Population = y
LOGARITHMIC SCALE CROSS-SECTION
5-INCH BASE

Plate 27.

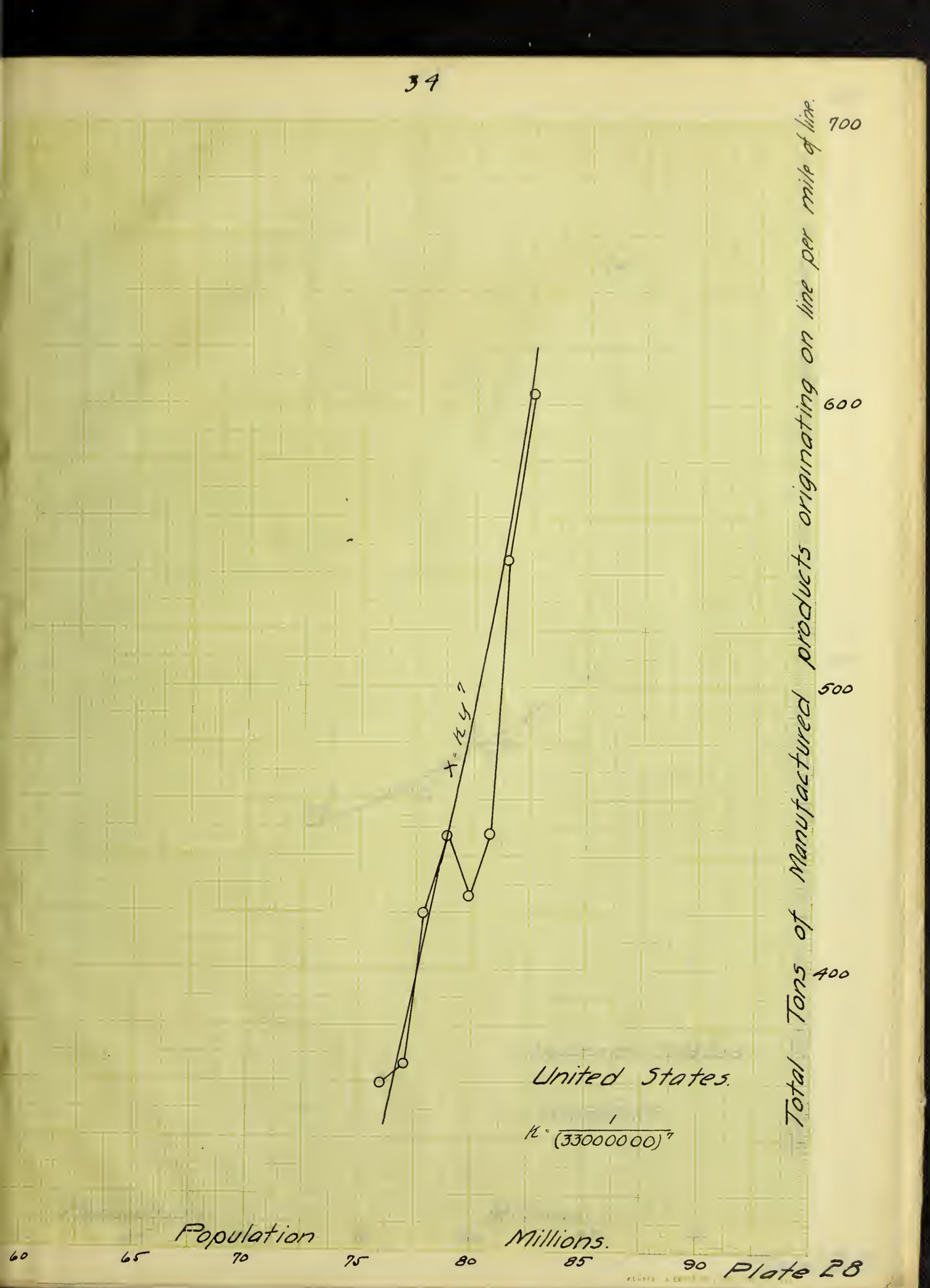

Total Tons of Manufactured products originating on line per mile of line.
700
600
500
400
$x = ky^7$
United States.
$k = \frac{1}{(33000000)^7}$
Population
Millions.
60
65
70
75
80
85
90

Plate 28

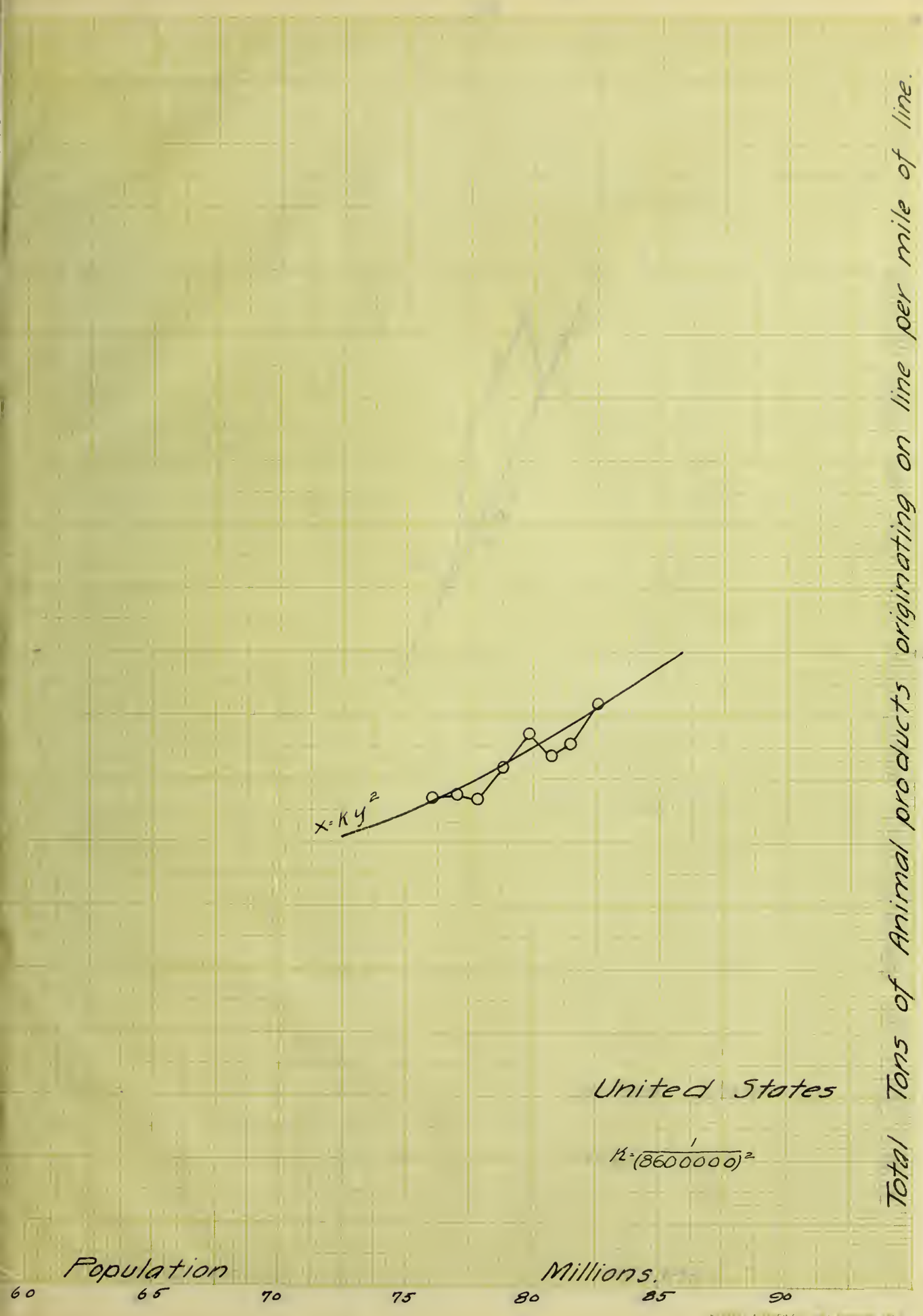
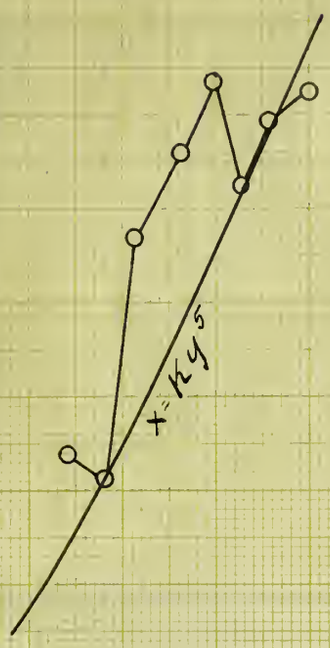

200
100
Total Tons of Animal products originating on line per mile of line.
$x = Ky^2$
United States
$K = \frac{1}{(8600000)^2}$
Population
Millions.
60
65
70
75
80
85
90

Plate 29.



200

100

Total Tons of Merchandise originating on line per mile of line.

United States

$k = \frac{1}{(30000000)^7}$

Population

Millions

60 65 70 75 80 85 90

Plate 30.

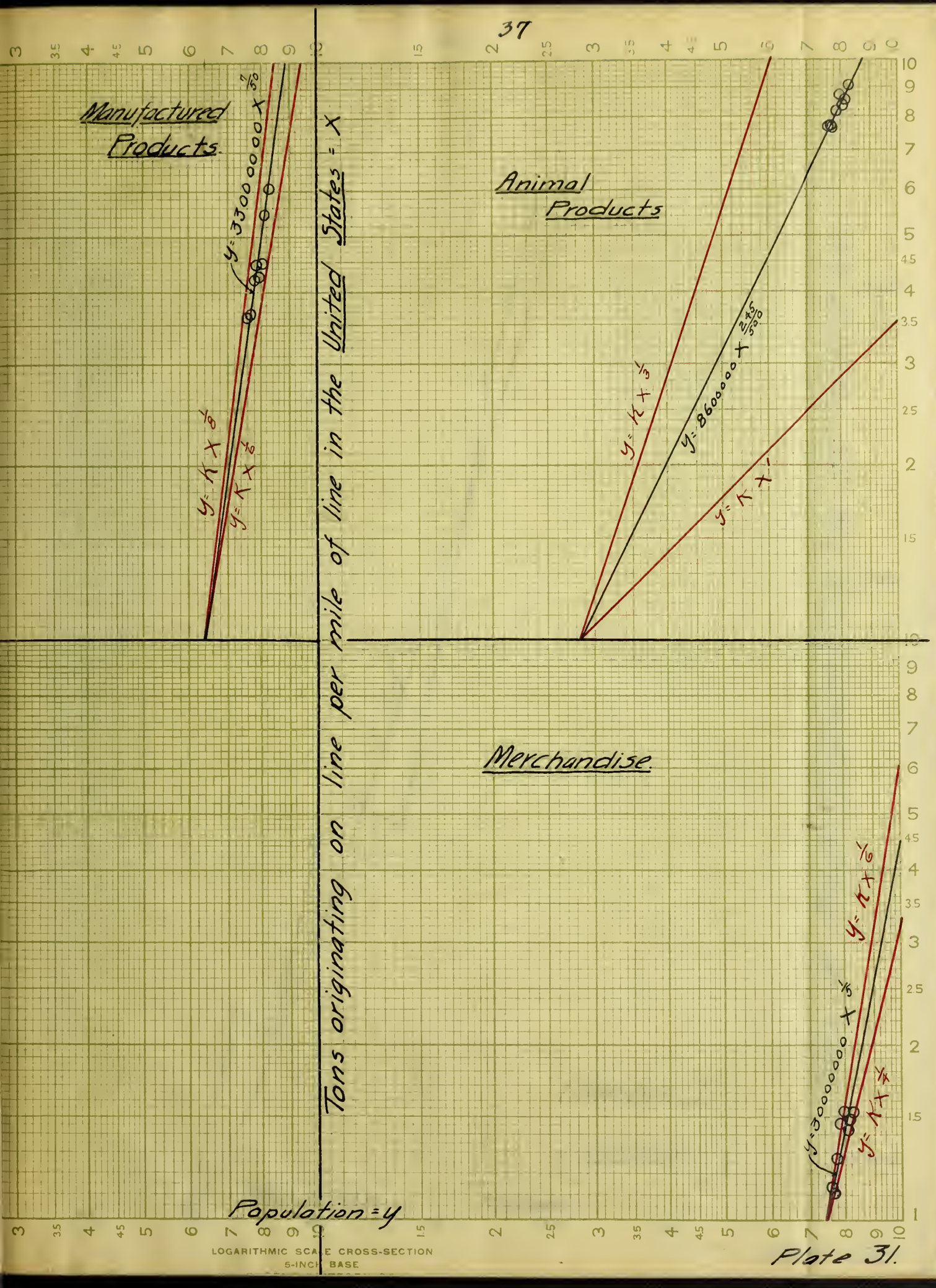

Manufactured Products.
y = 33000000 x^{1/3.50}
y = x^{1/3.5}
y = x^{1/3.8}
Animal Products
y = 8600000 x^{2.45/3.10}
y = x^{1/3}
y = x^{1/1}
Merchandise.
y = 30000000 x^{1/3.5}
y = x^{1/3.5}
y = x^{1/3}
Tons originating on line per mile of line in the United States = X
Population = y
LOGARITHMIC SCALE CROSS-SECTION
5-INCH BASE

Plate 31.

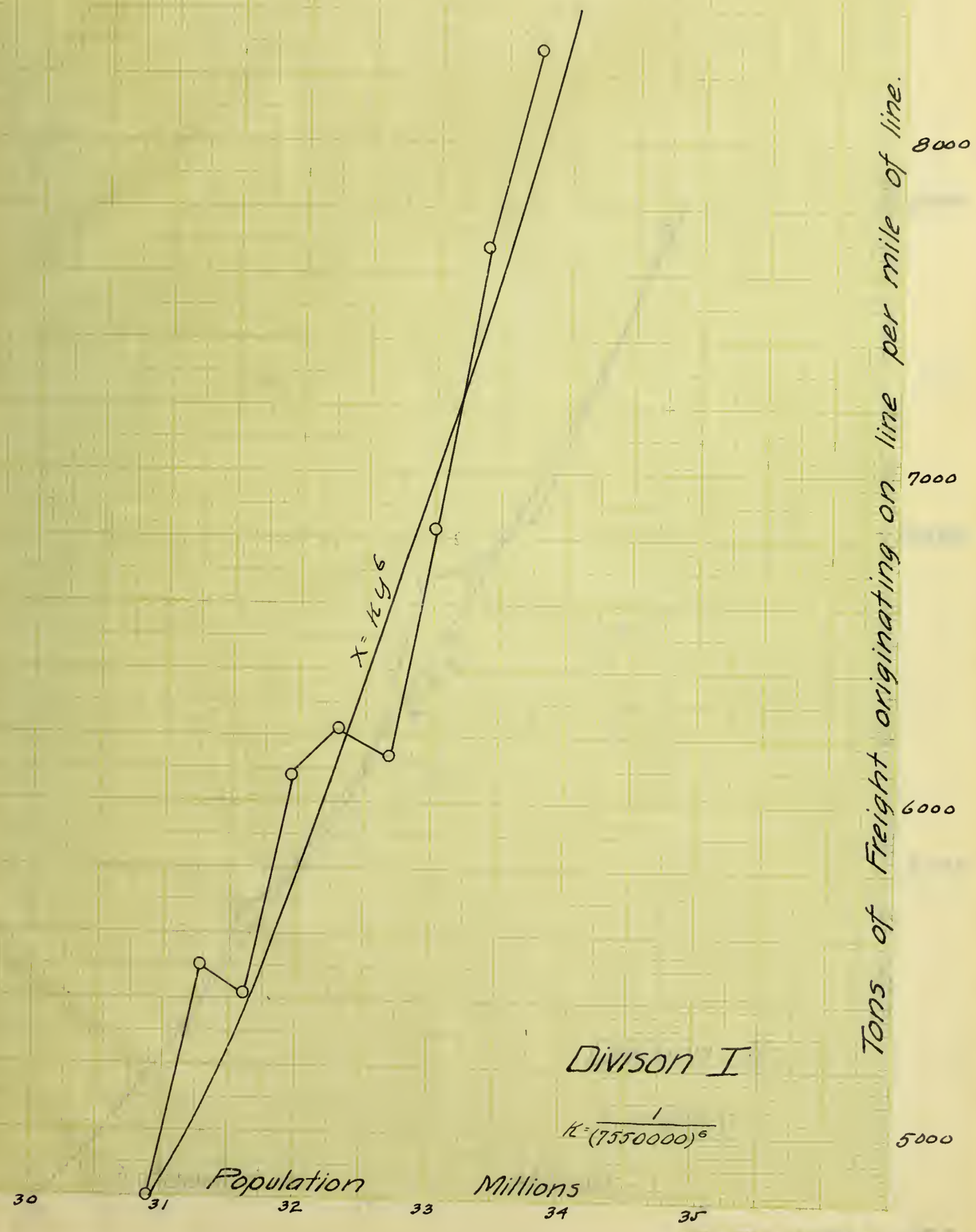
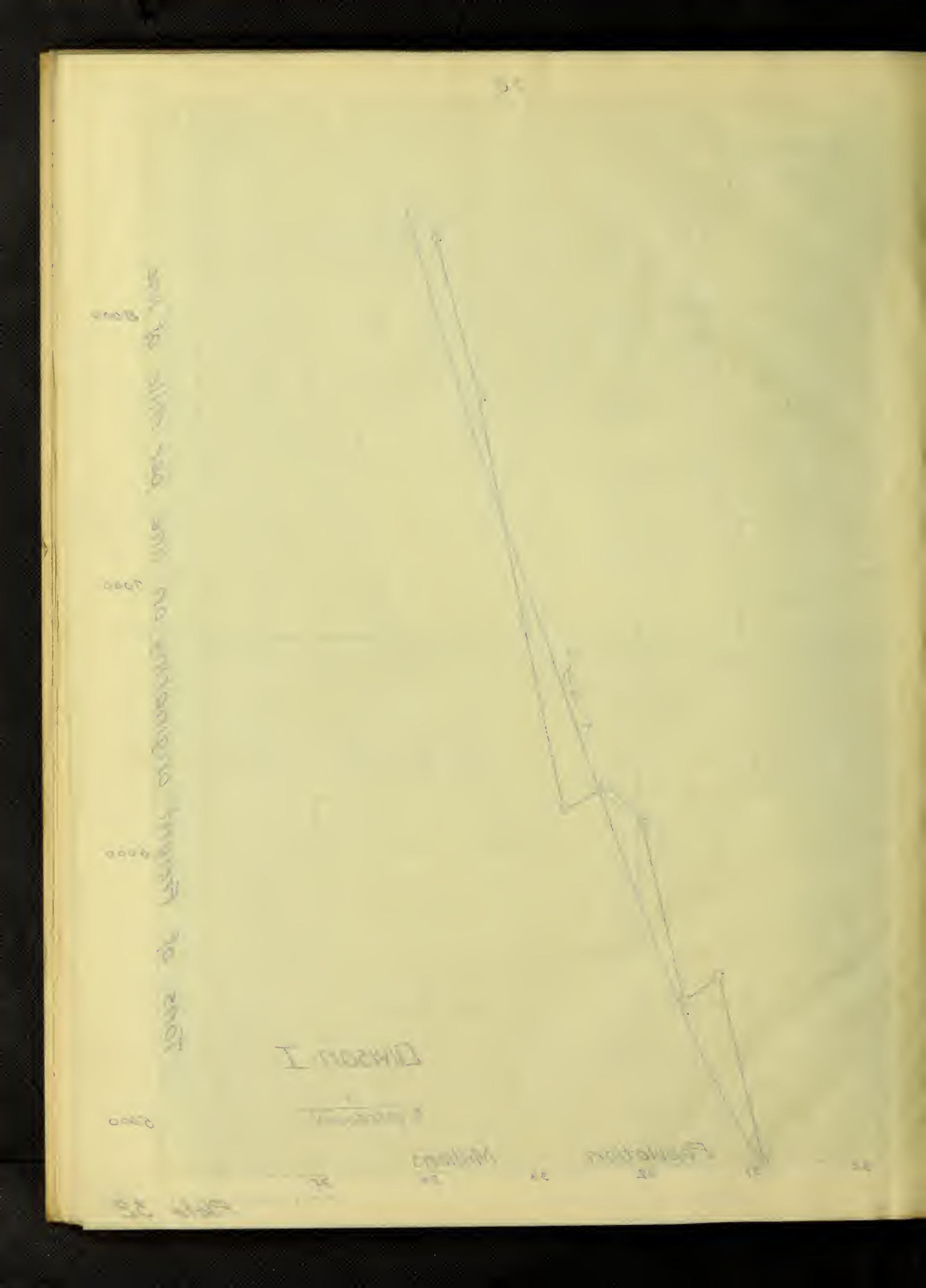

Tons of Freight originating on line per mile of line.
8000
7000
6000
5000
$x = ky^6$
Divison I
$k = \frac{1}{(7550000)^6}$
Population
Millions
30
31
32
33
34
35

Plate 32



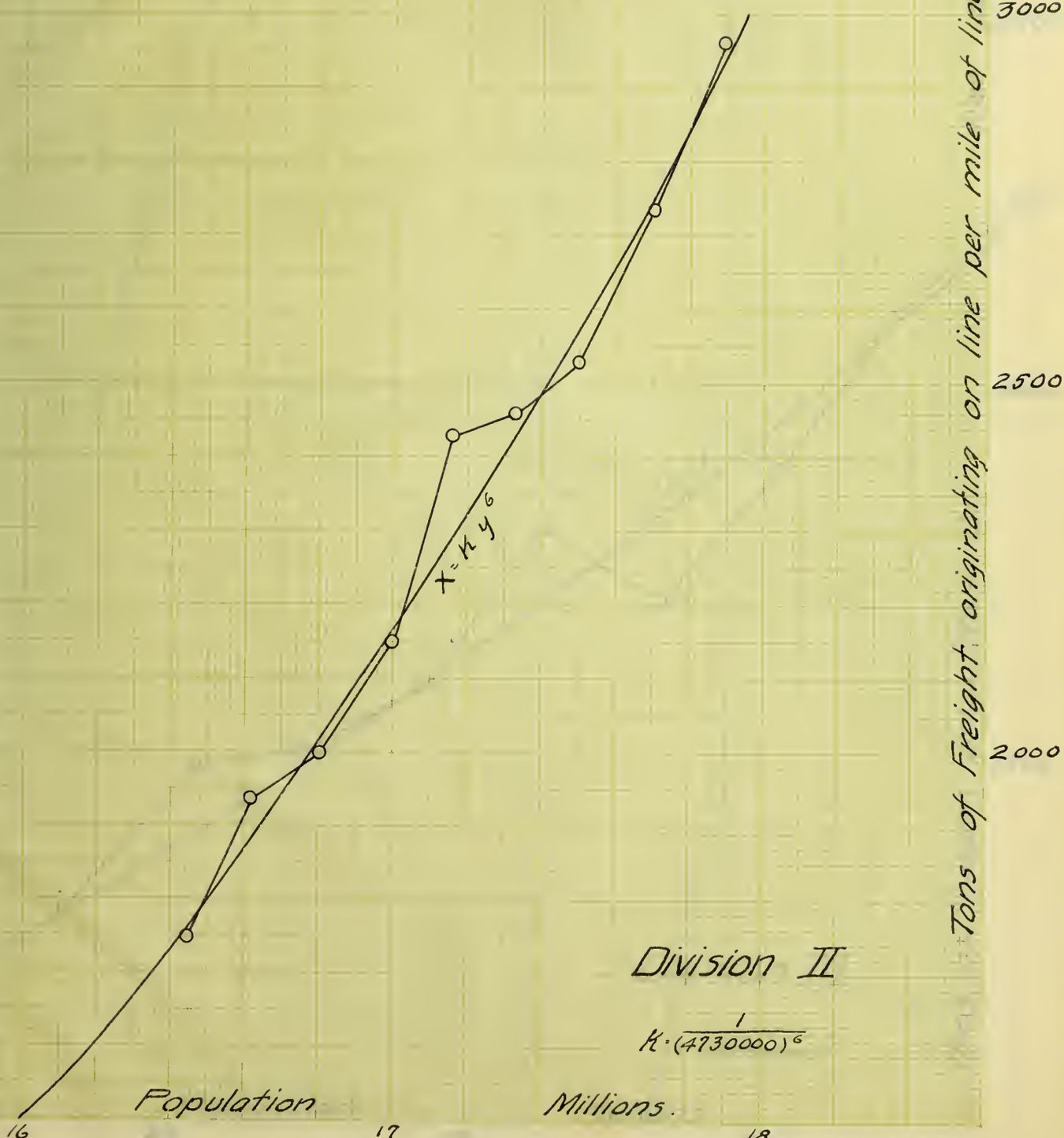
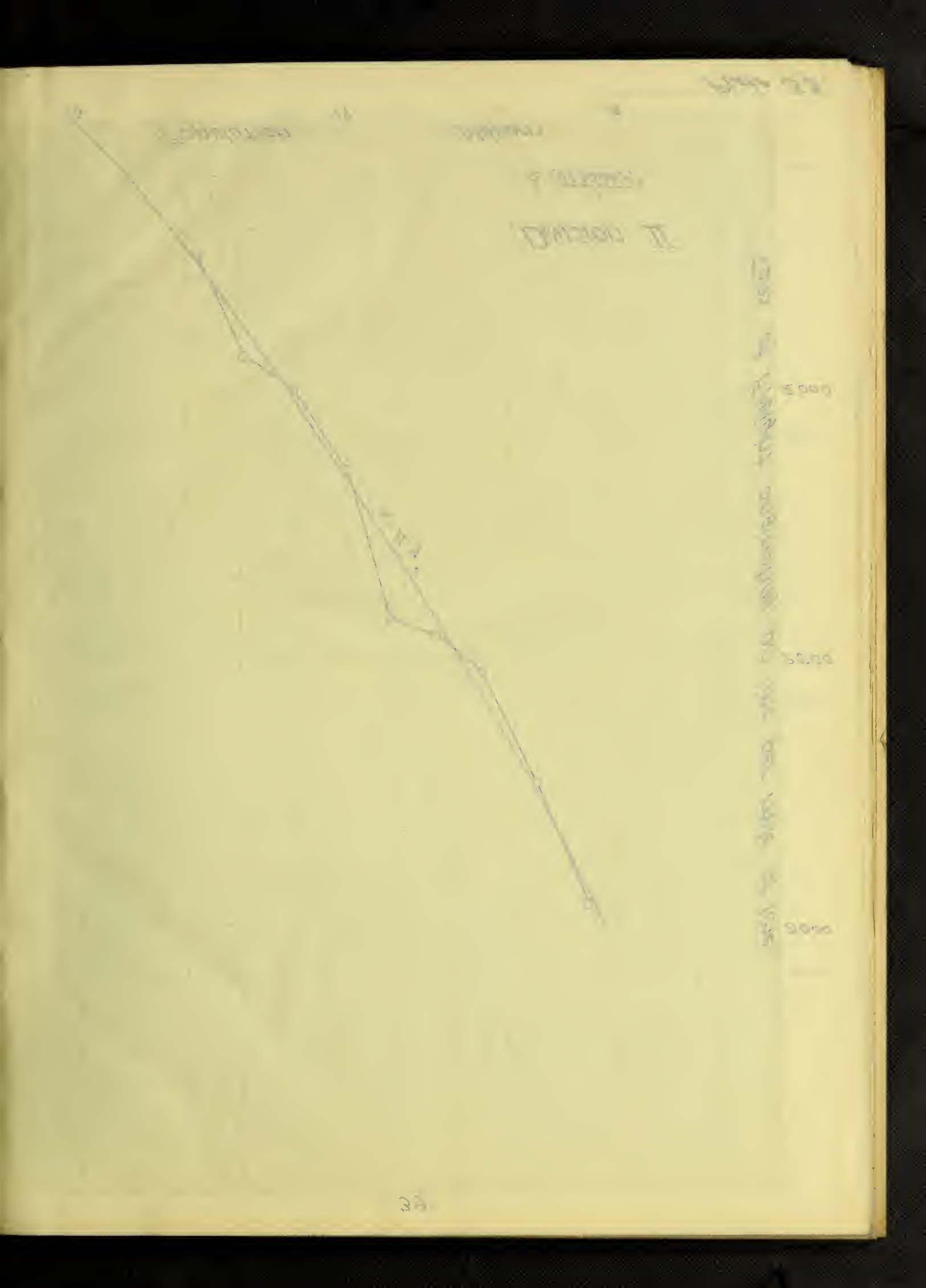

3000
2500
2000
Tons of Freight originating on line per mile of line.
$x = k y^6$
Division II
$\frac{1}{k \cdot (4730000)^6}$
Population
Millions.
16
17
18

Plate 33.



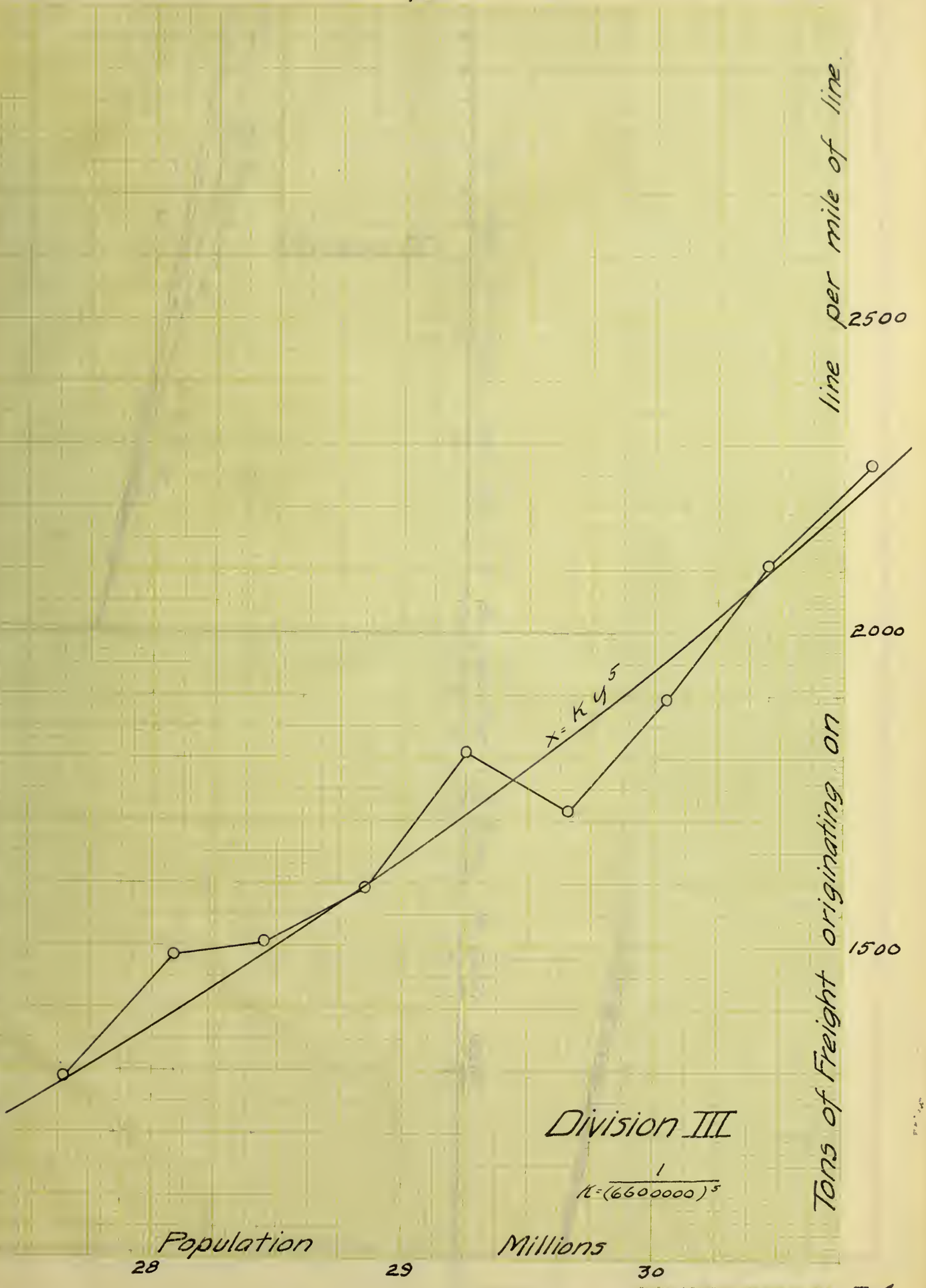
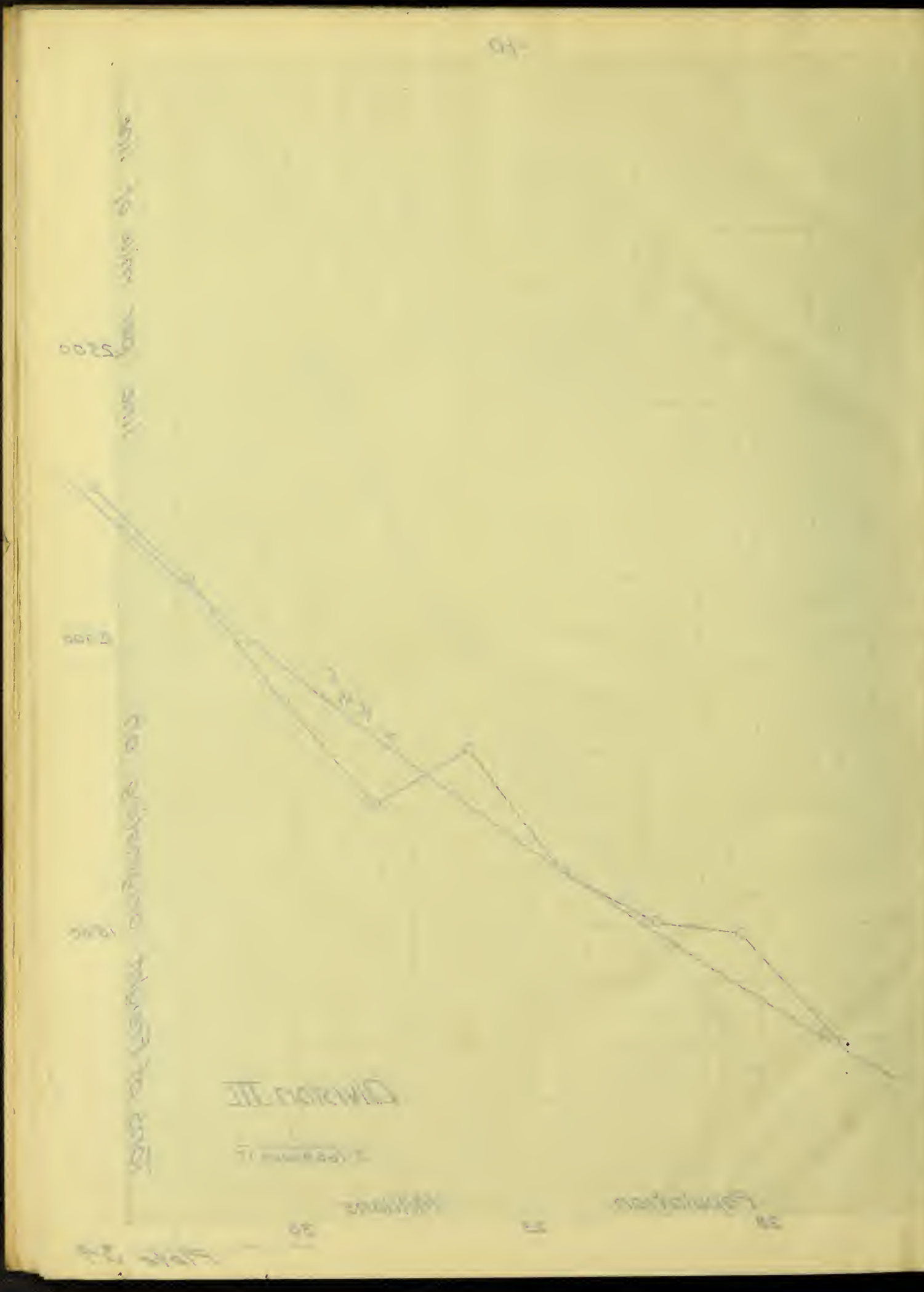
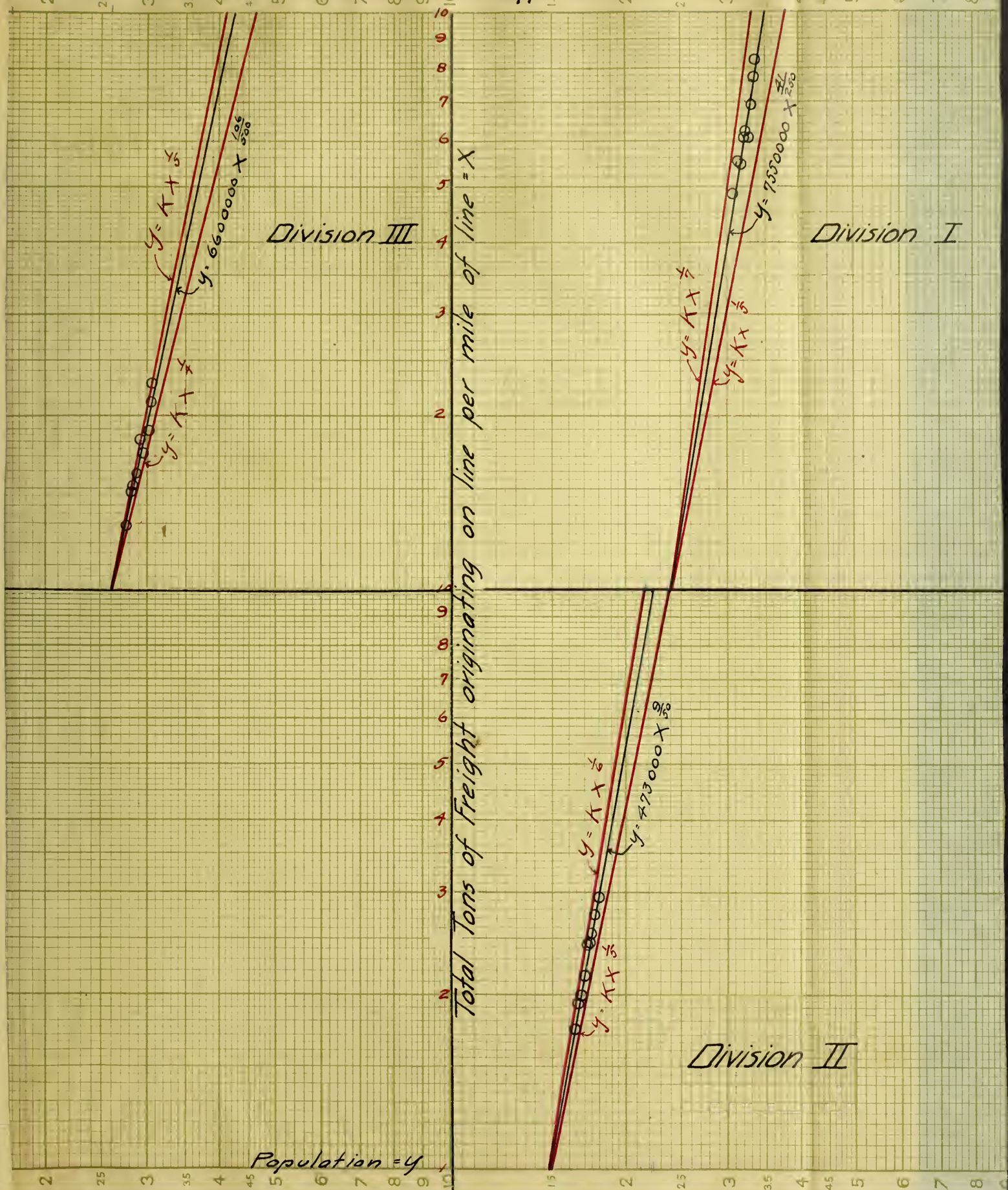

Tons of Freight originating on line per mile of line.
2500
2000
1500
$x = k y^5$
Division III
$k = \frac{1}{(6600000)^5}$
Population
Millions
28
29
30

Plate 34




Division III
Division I
Division II
Total Tons of Freight originating on line per mile of line = Y
Population = y
y = 660000 x 1.06/2.00
y = 755000 x 1.11/2.00
y = 473000 x 0.96/2.00
y = x + 1/5
y = x + 1/4

LOGARITHMIC SCALE CROSS-SECTION
5-INCH BASE
EUGENE DIETZGEN CO

Plate 35

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